

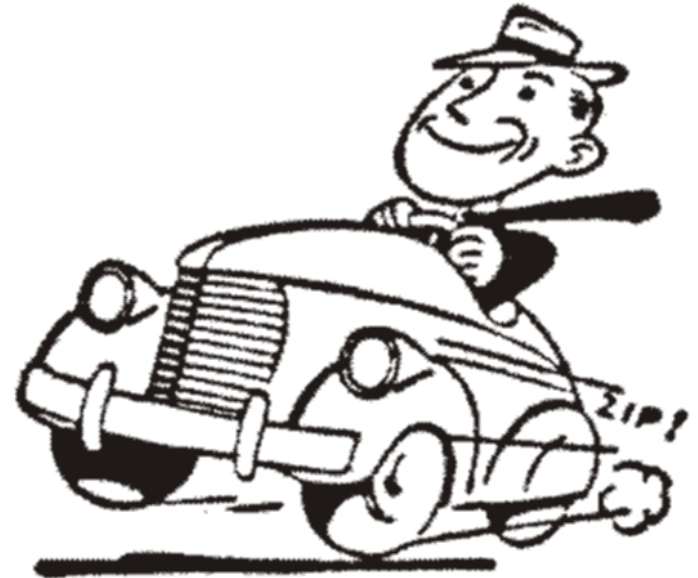


Technology and Applications in Transportation

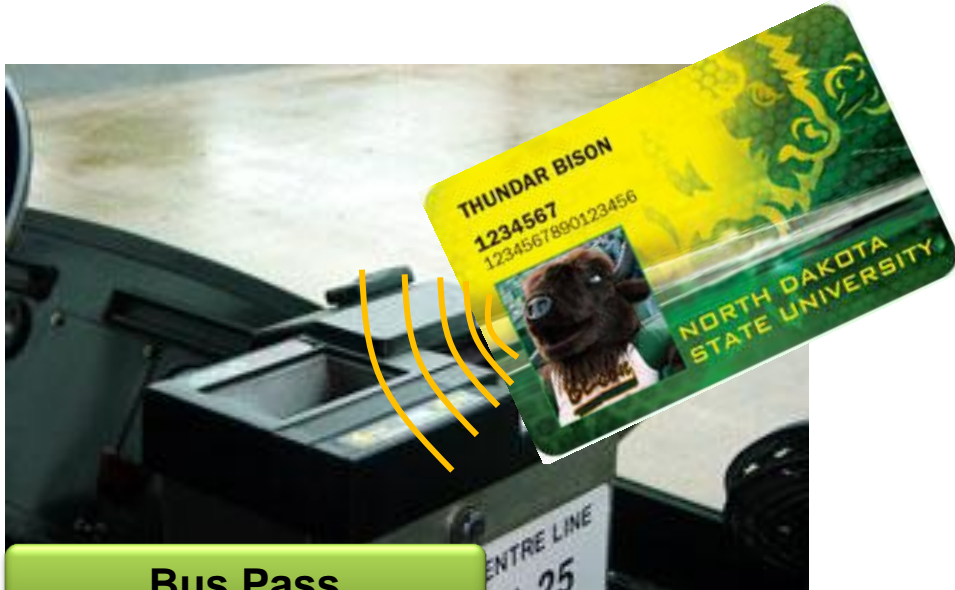
Raj Bridgelall

Raj.Bridgelall@ndsu.edu

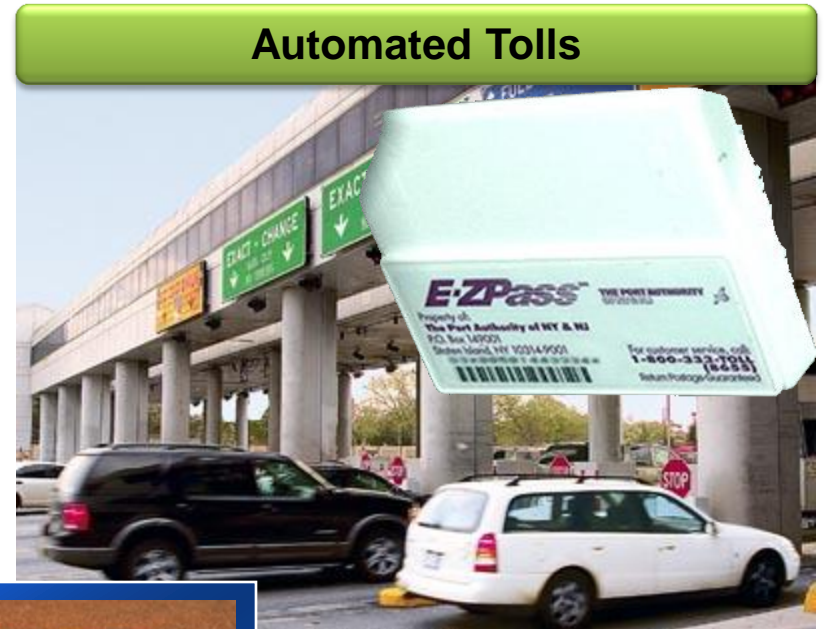
The only two cars in [Van Wert](#) County, Ohio (population 784) in 1891 made transportation history ...



Do You RFID?



Bus Pass



Automated Tolls



Contactless Payment



Automotive Security



Outline of Talk

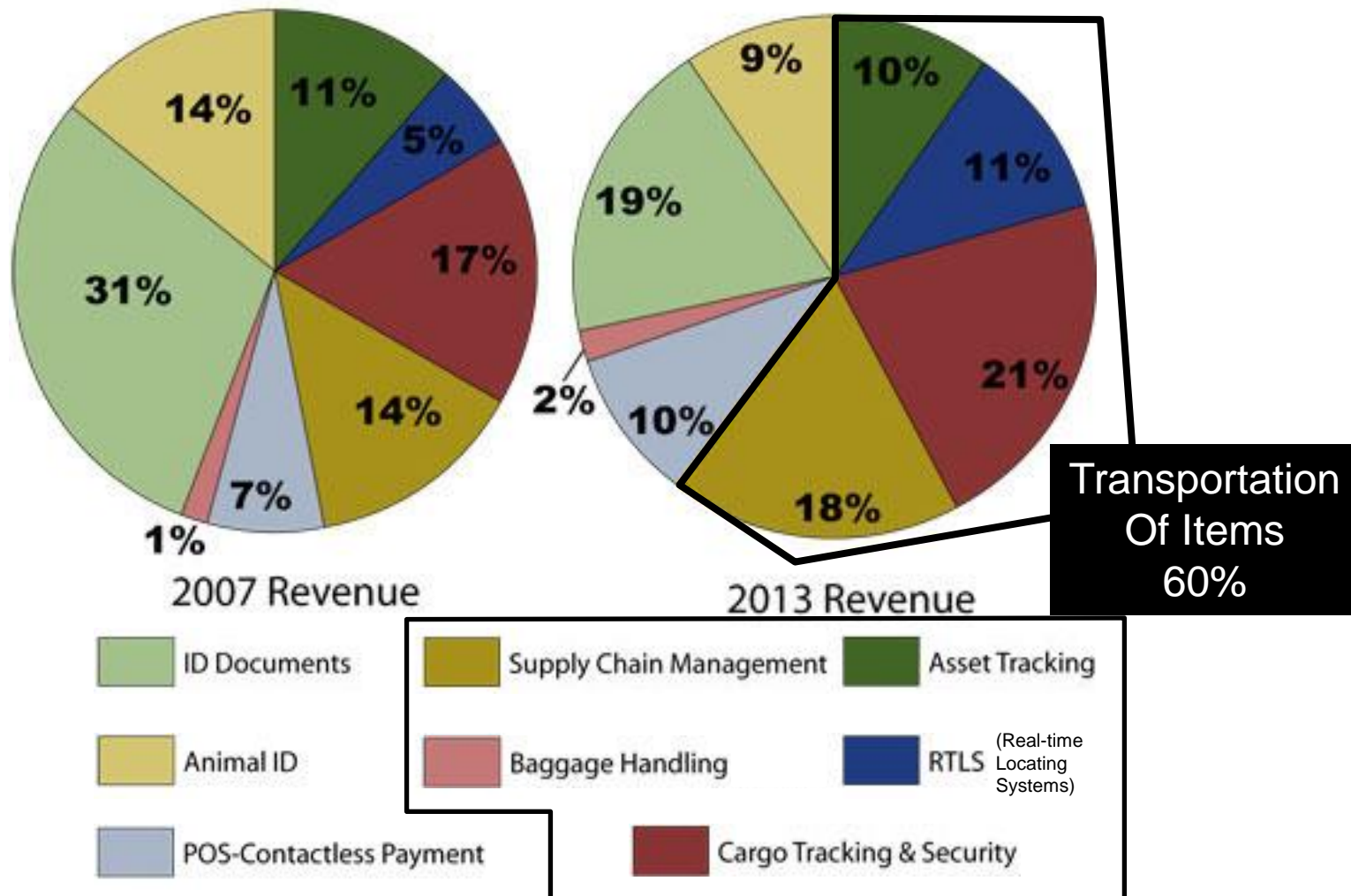
- Introduction
- Market
- Applications
- History
- Taxonomy (place in the wireless landscape)
- How it works (illustrative)
- Conclude

Key Takeaways

- **Transportation and logistics have strong ties to RFID**
- **RFID has transformative potential if used correctly; disastrous if not**
- **RFID is simple in concept but there are many ‘surprises’ in practice**

Transportation & Logistics Share Dominates

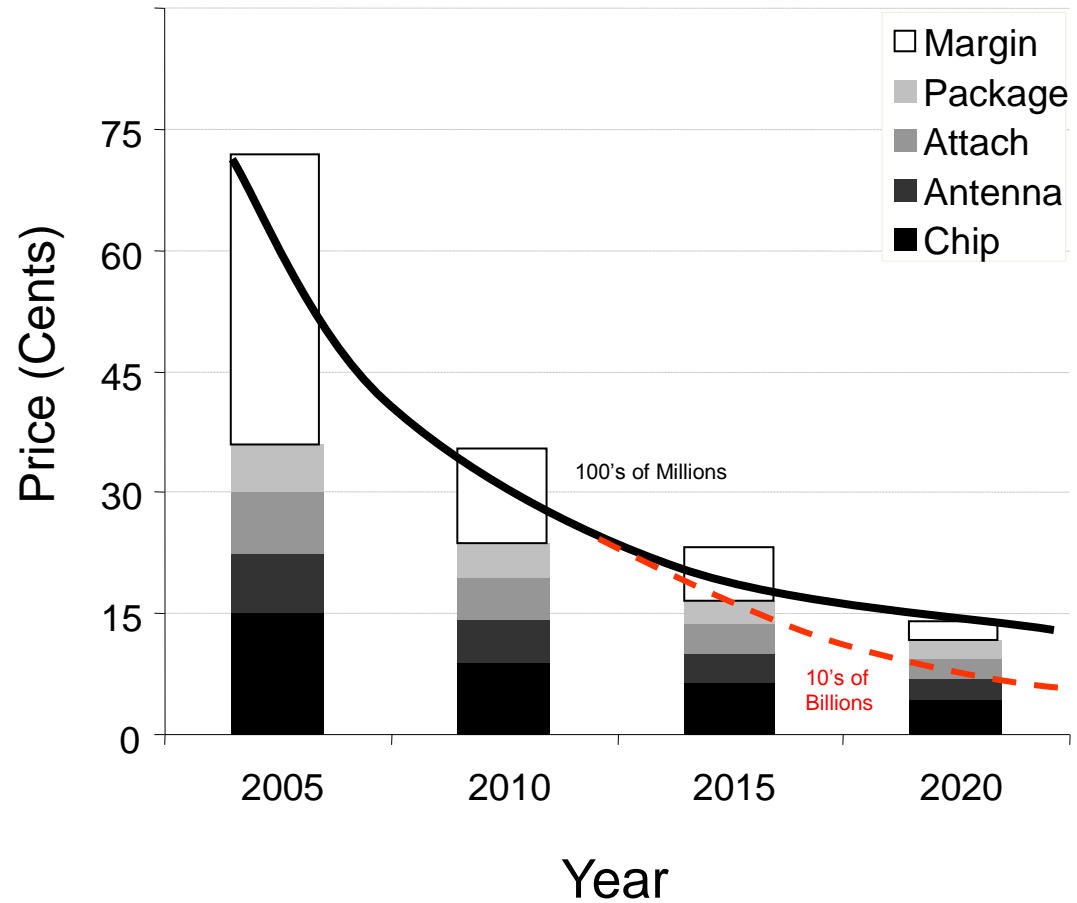
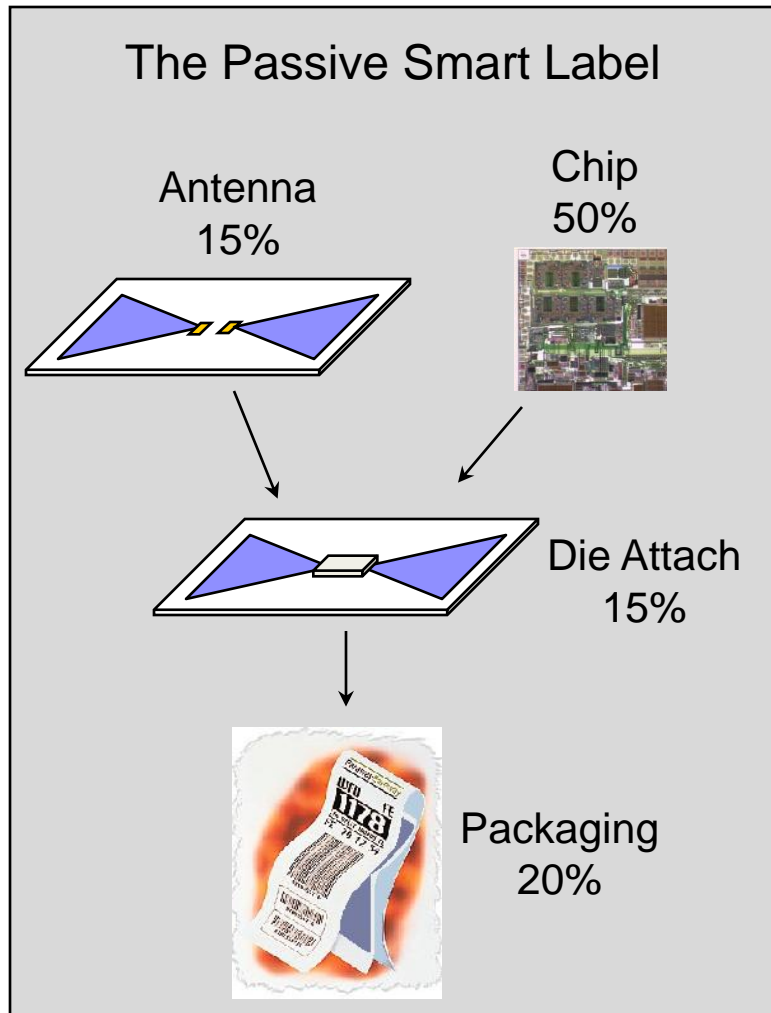
RFID Integration Services By Vertical Markets
World Market, 2007 vs. 2013 Moderate Forecast



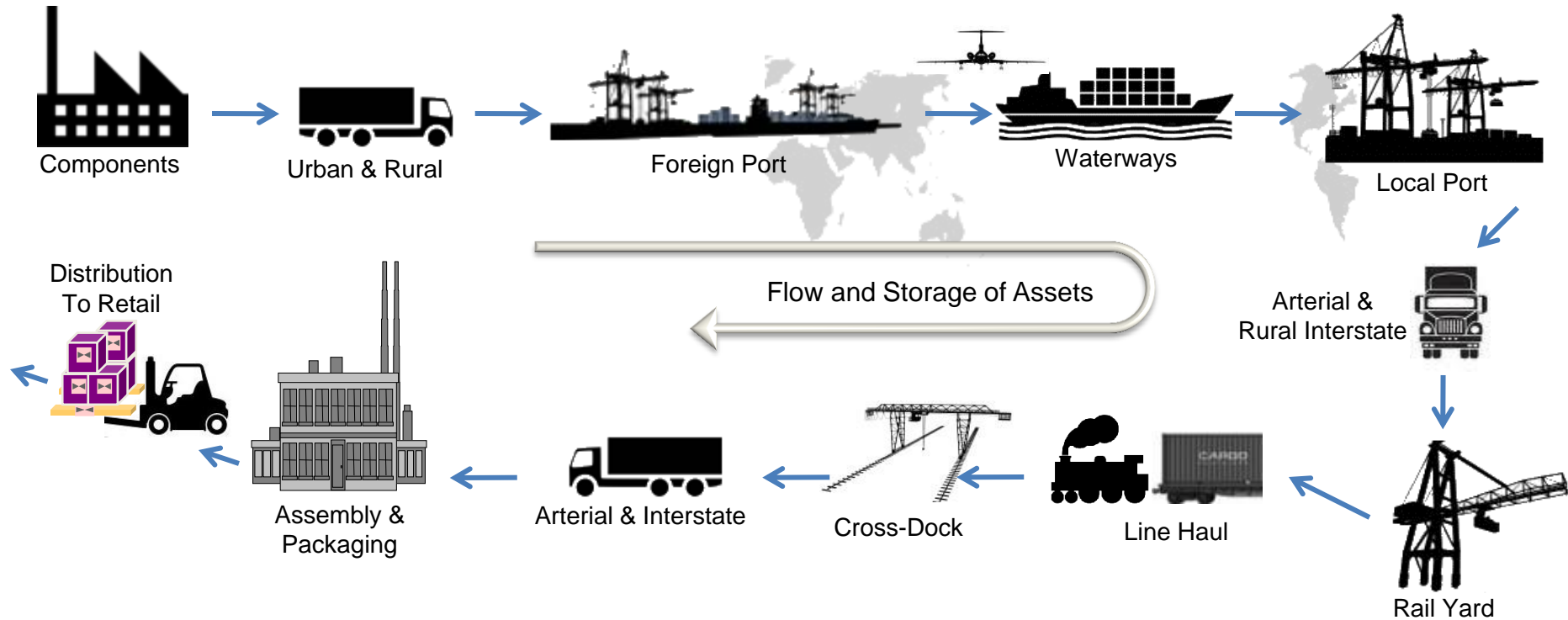
Total RFID Market = \$6B (2011)

Source: ABI Research

Passive Tag Minimum Cost Trends



A Typical Supply Chain

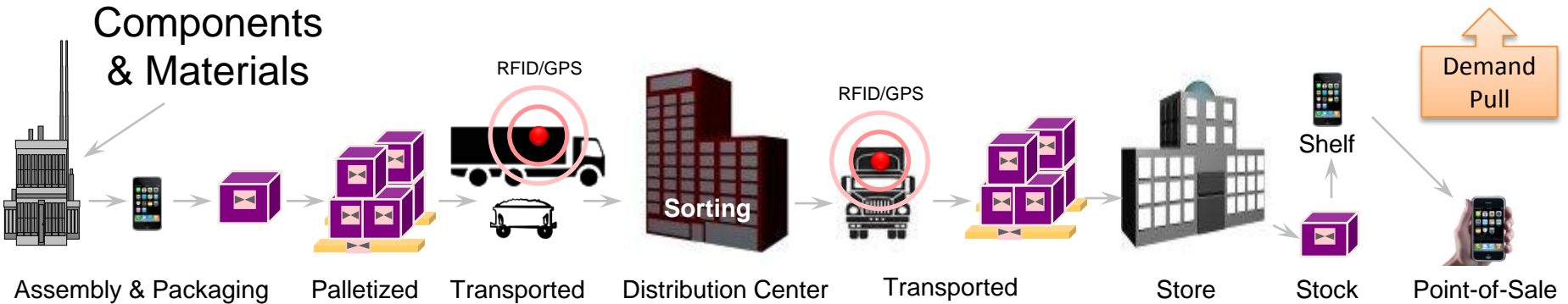


- Efficiency and reliability depends on ...
 - Transportation system performance and facility condition
 - Supplier performance
 - Regulatory and institutional barriers

Need
Real-Time
Information &
Asset Visibility

A Popular Passive RFID Application

Enabling Supply Chain Visibility



**Barcode
Source
Tagging**

**RFID/Barcode
Package
Aggregation**

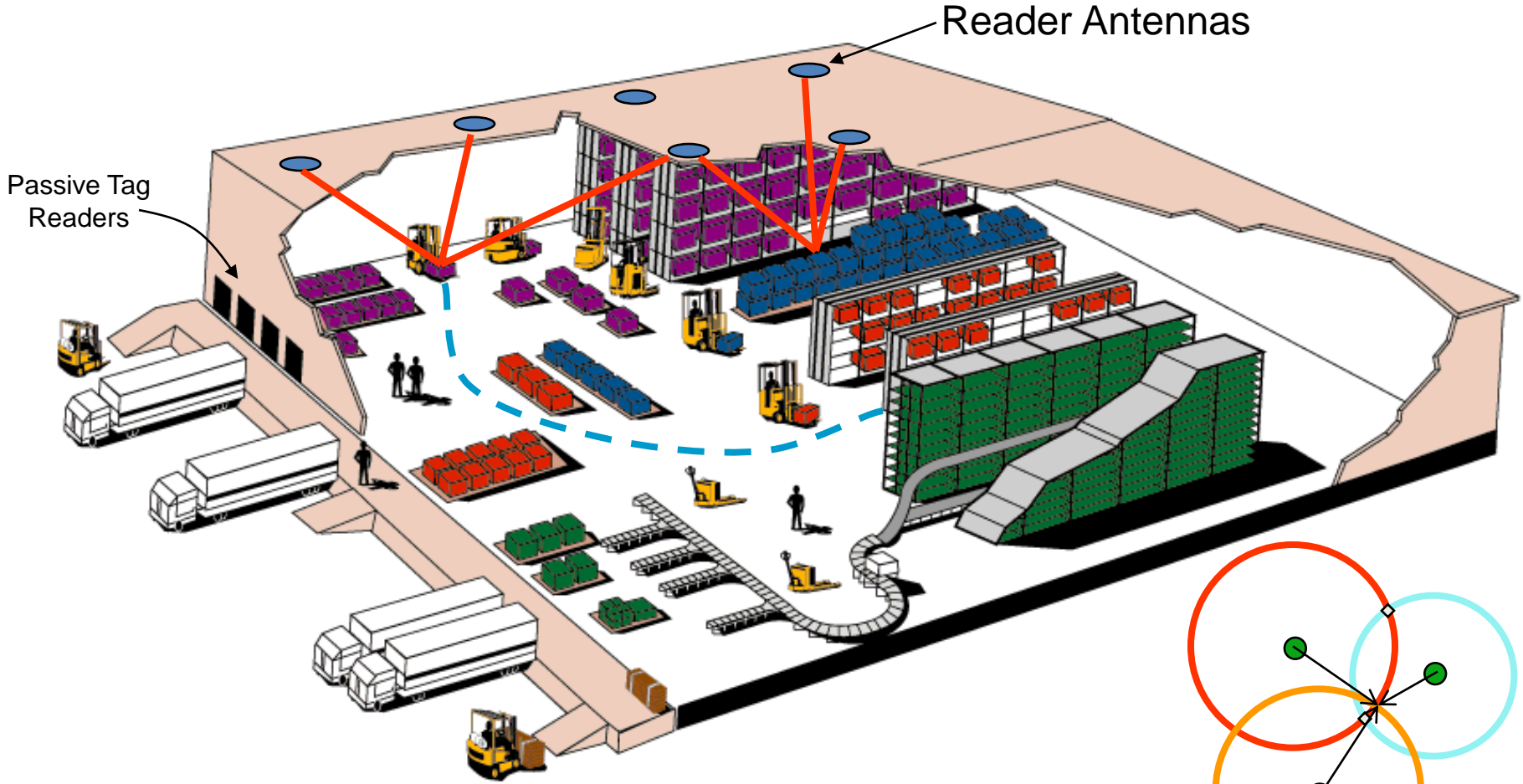
**Portal/Infrastructure Reading
(RFID/RTLS)
Unattended Auto-ID**

**RFID Shelf and
Hand-Held Reading**

**Barcode/EAS
Reading**

- The supply chain ‘loses’ \$37B/year¹ (worsens as GDP grows)
 - Goods damaged, spoiled, wrong delivery, diversion (theft) ...
- Some indirect costs from an unreliable transportation system
 - \$10 billion in goods “lost” during delivery process (U. of FL study)
 - 20% of perishables expire before they are sold (FDA study)
 - 15% of shoppers leave without finding an item (The GAP)

Indoor Real-time Location Tracking Systems



RTLS saves 50% of labor spent looking for items (Bernstein Research Statistics)

Location Trilateration

Emerging Applications for Every Mode

Roadways



- **Roadside asset** and inventory monitoring
- **Bridge** structural health monitoring
- **Tunnel** structural health monitoring

Railways

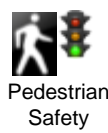


- Railcar and engine configuration
- Automatic control and signaling systems
- Rail condition monitor and inventory
- Tunnel safety checks

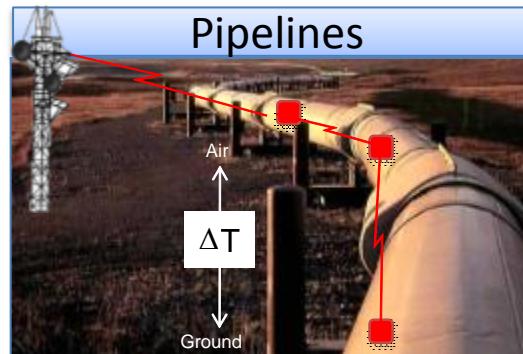
Airways



- Runway asset monitoring
- Vehicle access control
- Cargo safety and security
- Baggage tagging and tracking



Pipelines



- Condition monitoring
- Stress and breakage monitoring
- Corrosion monitoring

Waterways



- Cargo tracking and security
- Traffic and signaling controls
- Tunnel safety

Intermodal



- Crane safety systems
- Traffic signaling systems

Asset Visibility and Security

HAZMAT



- Asset safety monitoring
- Asset identification and inspection

Productivity



- Load efficiency
- Truck Identification

Cold Chain



- Product Temperature Monitoring
- Asset identification and authentication

Construction Materials Tracking



- Quality control
- Asset location tracking
- Inventory management

Harvest Distribution



- Quality management and lot tracking
- Weigh scales and distribution points
- Packaging and distribution points

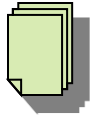
Asset Tracking



- Tamper and condition monitoring
- RTLS

Brief History of RFID Development

1940	1950	1960	1970	1980	1990	2000
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1948

Harry Stockman
*“Communication
 By Means of
 Reflected Power”*



1966

Checkpoint &
 Sensormatic
 EAS

Commercialization
*1-bit Electronic Article
 Surveillance*



1979

First
 Implantable
 RFID for
 Livestock



1996

LA Adopts
 Pet Tagging



1950's

D.B. Harris Patents
*“Radio Transmission Systems with
 Modulatable Passive Responder”*



1992

First RFID
 Toll
 Collection
 System in
 U.S.

2003

WAL*MART®
 Mandate



1975

Los Alamos
 Scientific Labs
Declassified
*“Short-range
 Radio-telemetry
 for Electronic
 Identification
 using Modulated
 Backscatter”*



1940's
 RADAR
 Perfected
 in WWII



1959

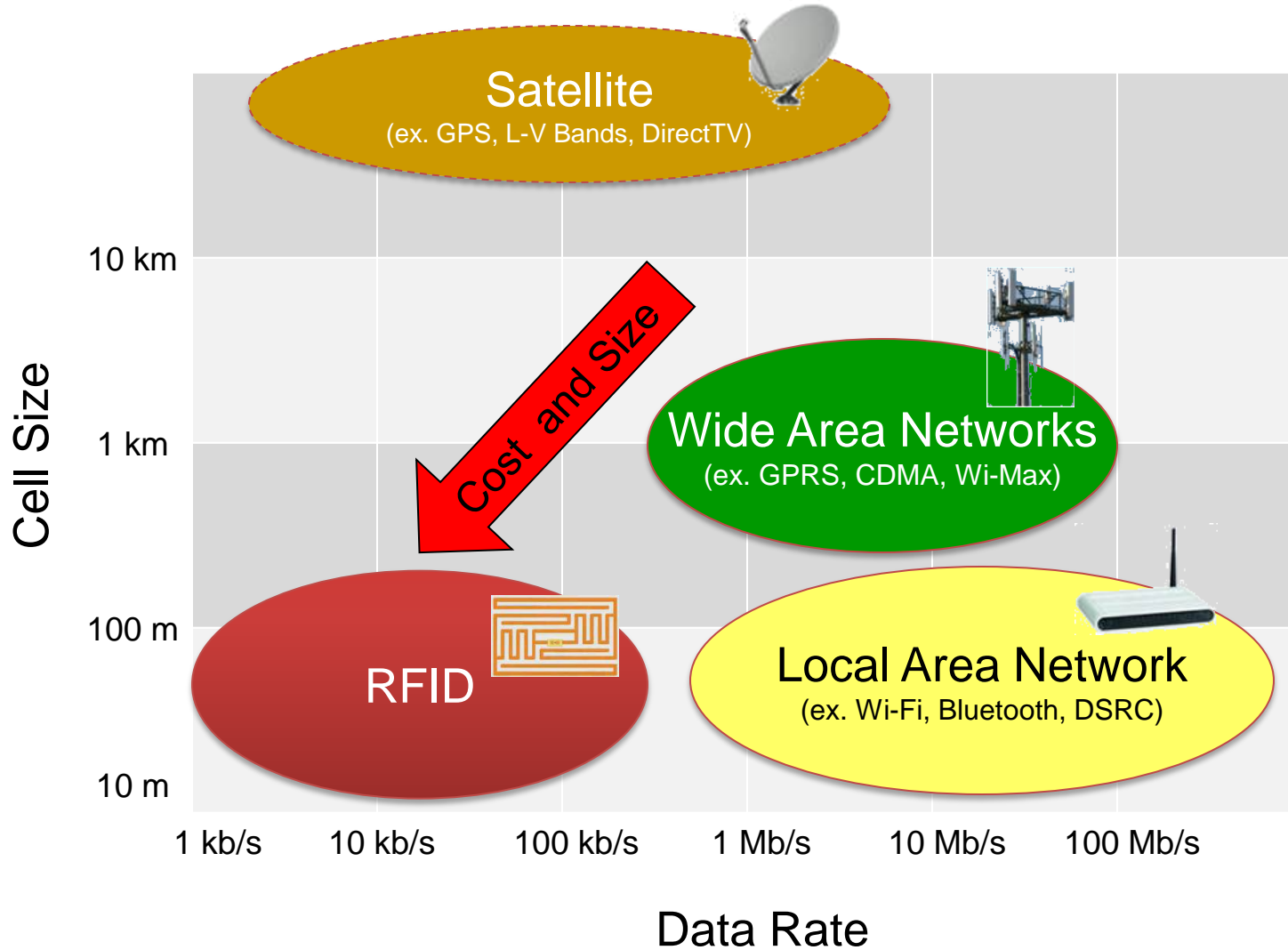
Friend or Foe
 Military Long Range
 Transponder

2003

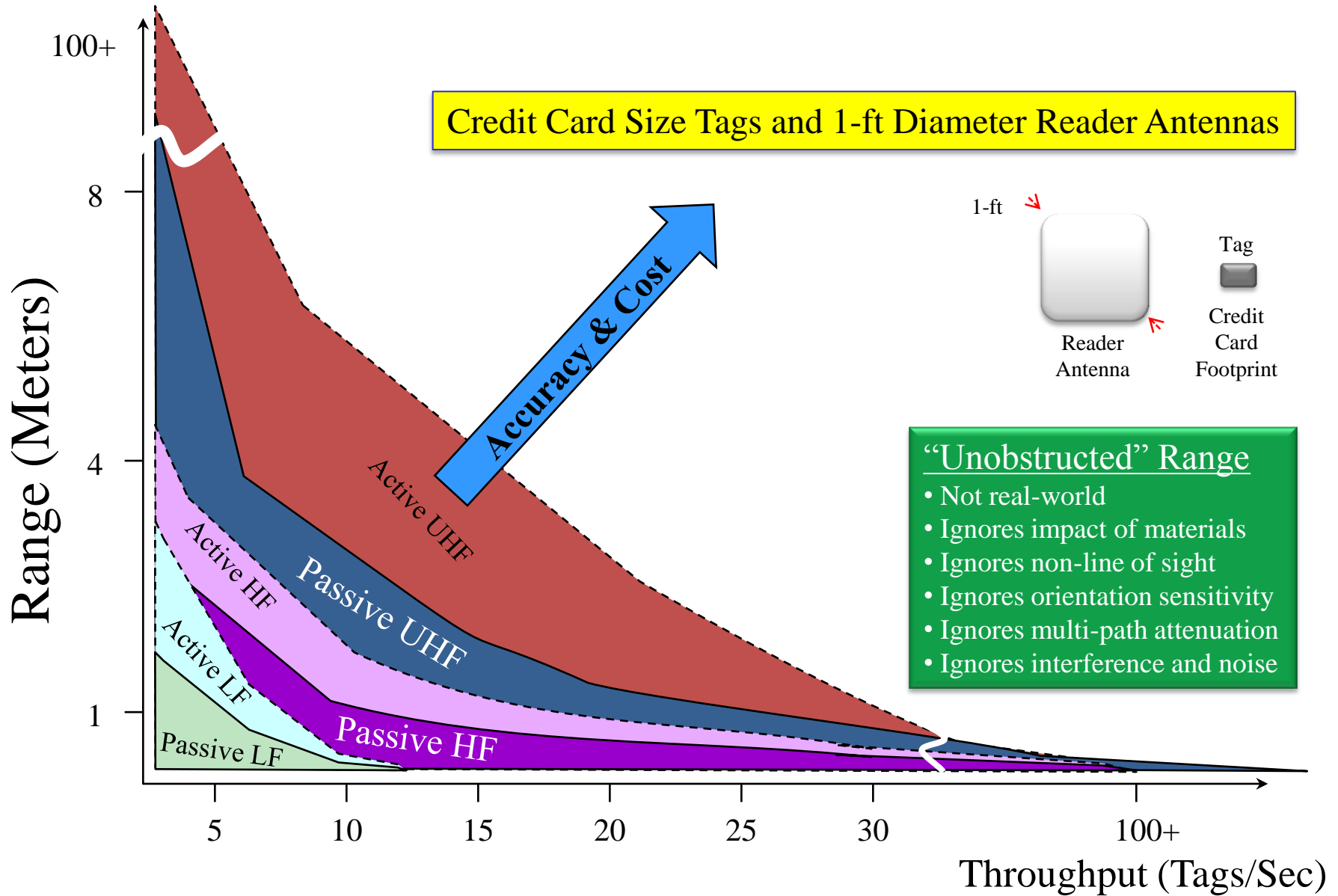


Military Mandate




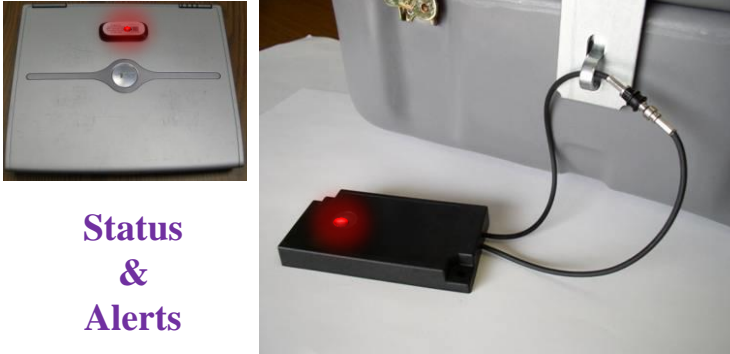
Taxonomy – Wireless Landscape



RFID Performance Envelope



RFID Power Classification

	No Batteries	Batteries
Reflected Energy	<p>Passive</p>  <p>Three images illustrating passive RFID: a vertical white tag with a black antenna, a square purple tag with a white antenna, and a yellow forklift in a warehouse with a red container.</p>	<p>Semi-Passive</p>  <p>Passive Compatible Sensor Tags</p> <p>A photograph of a semi-passive RFID tag with a red battery and a white antenna.</p>
Transmitted Energy	<p>Energy Harvesting</p>  <p>Two images illustrating energy harvesting: a hand holding a silver mobile phone with a gold RFID tag on the back, and a hand holding a white RFID tag with a solar panel.</p>	<p>Active</p>  <p>Status & Alerts</p> <p>Two images illustrating active RFID: a grey rectangular tag with a red button, and a black rectangular tag with a red light and a cable connected to a power source.</p>

Why so many types of RFID?

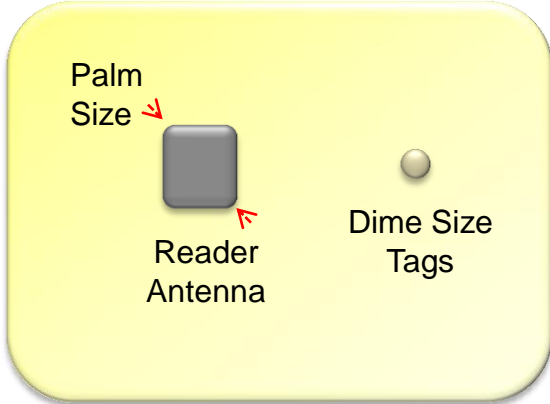
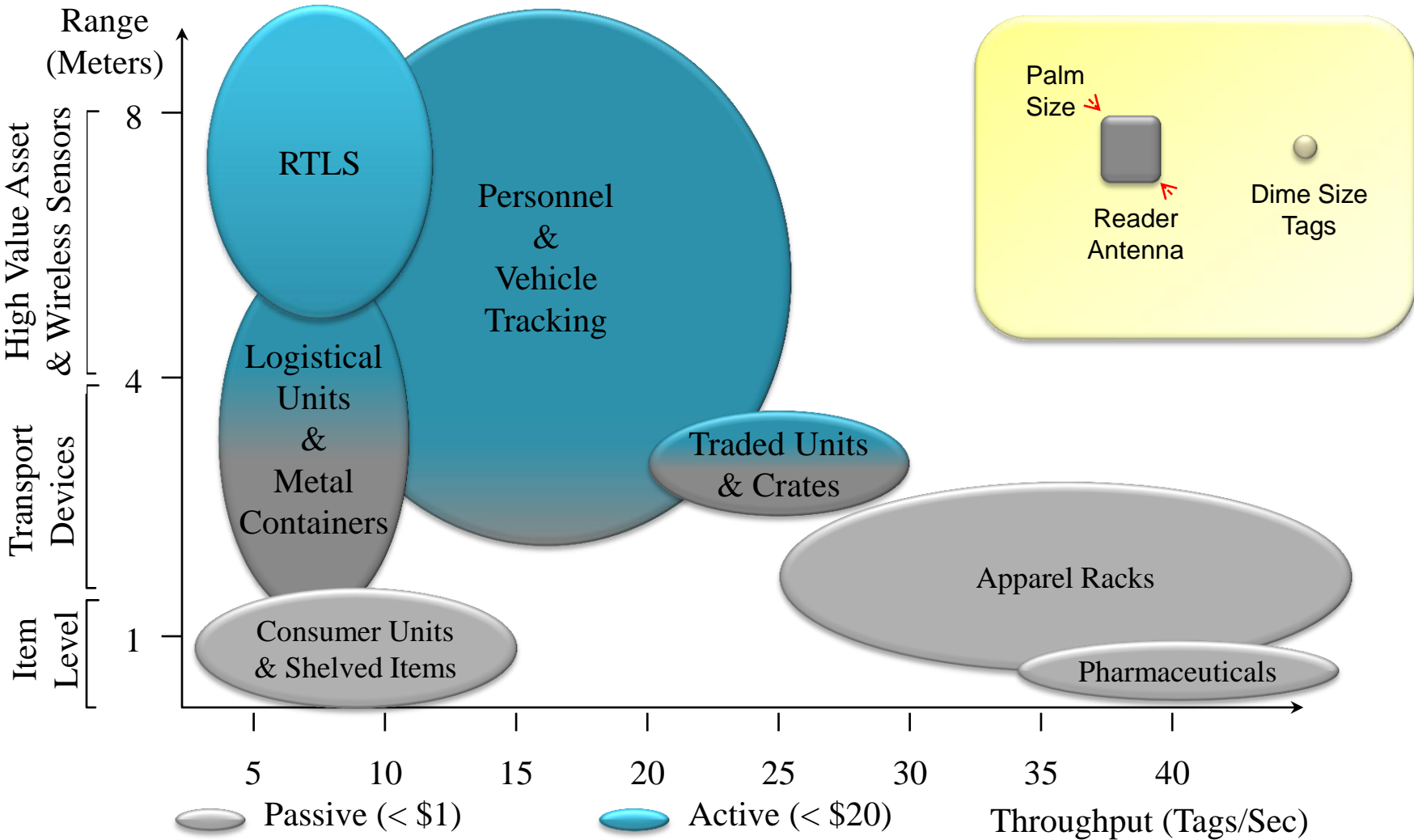
Radio Frequency Technology Classification

		Near-Field		Far-Field	
Radiated Emissions		e.g. RuBee (IEEE P1902.1), NFC (ISO 18092)		e.g. Wi-Fi (IEEE 802.11), UHF RFID (ISO18000-7)	
		Benefits <ul style="list-style-type: none"> • Robust link around dense RF media • Magnetic field zone control • Simple narrow-band protocols maximize battery life 	Deficiencies <ul style="list-style-type: none"> • Range limited to antenna loop diameter • Multi-tag arbitration speed limited by data rate 	Benefits <ul style="list-style-type: none"> • Long range from RF propagation and higher transmit power • High multi-tag arbitration rates possible due to larger bandwidth & data-rate 	Deficiencies <ul style="list-style-type: none"> • Some bands require spread spectrum and complex multiple access protocols; leads to higher power consumption • Poor zone control
Backscatter		e.g. HF RFID (ISO 14443), LF RFID (ISO 14223-1)		e.g. UHF RFID (ISO18000-6 & EPC)	
		Benefits <ul style="list-style-type: none"> • Excellent zone control • Robust near-field energy harvesting for passive HF/LF RFID • Robust media penetration 	Deficiencies <ul style="list-style-type: none"> • Backscatter reader sensitivity and loop antenna diameter limits practical range to within one meter • Multi-tag arbitration limited by bandwidth and data rate 	Benefits <ul style="list-style-type: none"> • Tens of meters of range for passive tags • Longer range for semi-passive tags; limited primarily by reader sensitivity • High multi-tag arbitration rate • Longer battery life 	Deficiencies <ul style="list-style-type: none"> • Poor zone control • Poor RF media penetration • Highly orientation sensitivity due to weaker backscatter and multi-path propagation

External Power Source (e.g. RF, Vibration, Light)
Internal Power Source (e.g. Batteries)

A one size fits all solution is illusive.

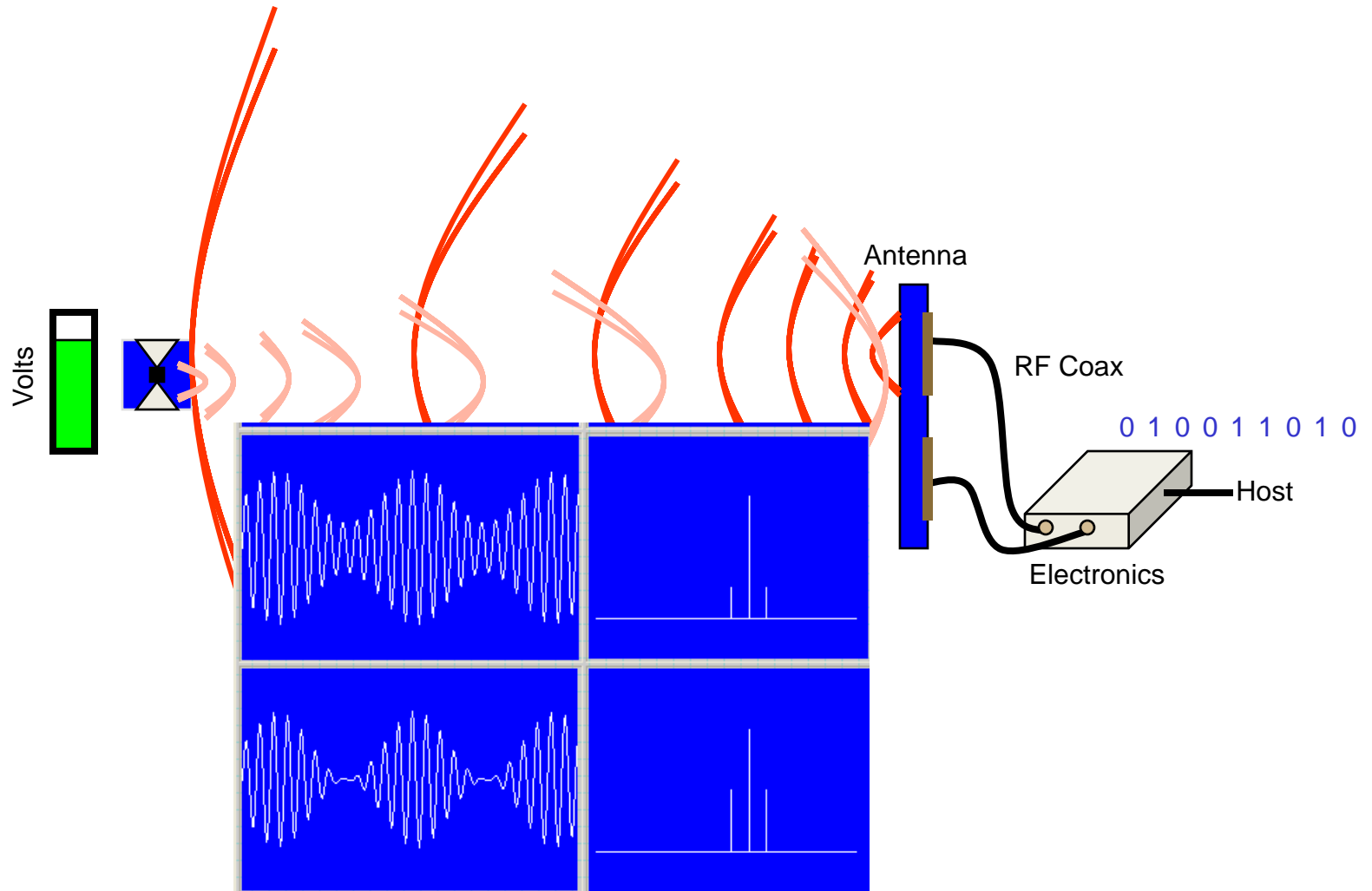
Application and Technology Mapping



How does Passive RFID work
(without a battery)?

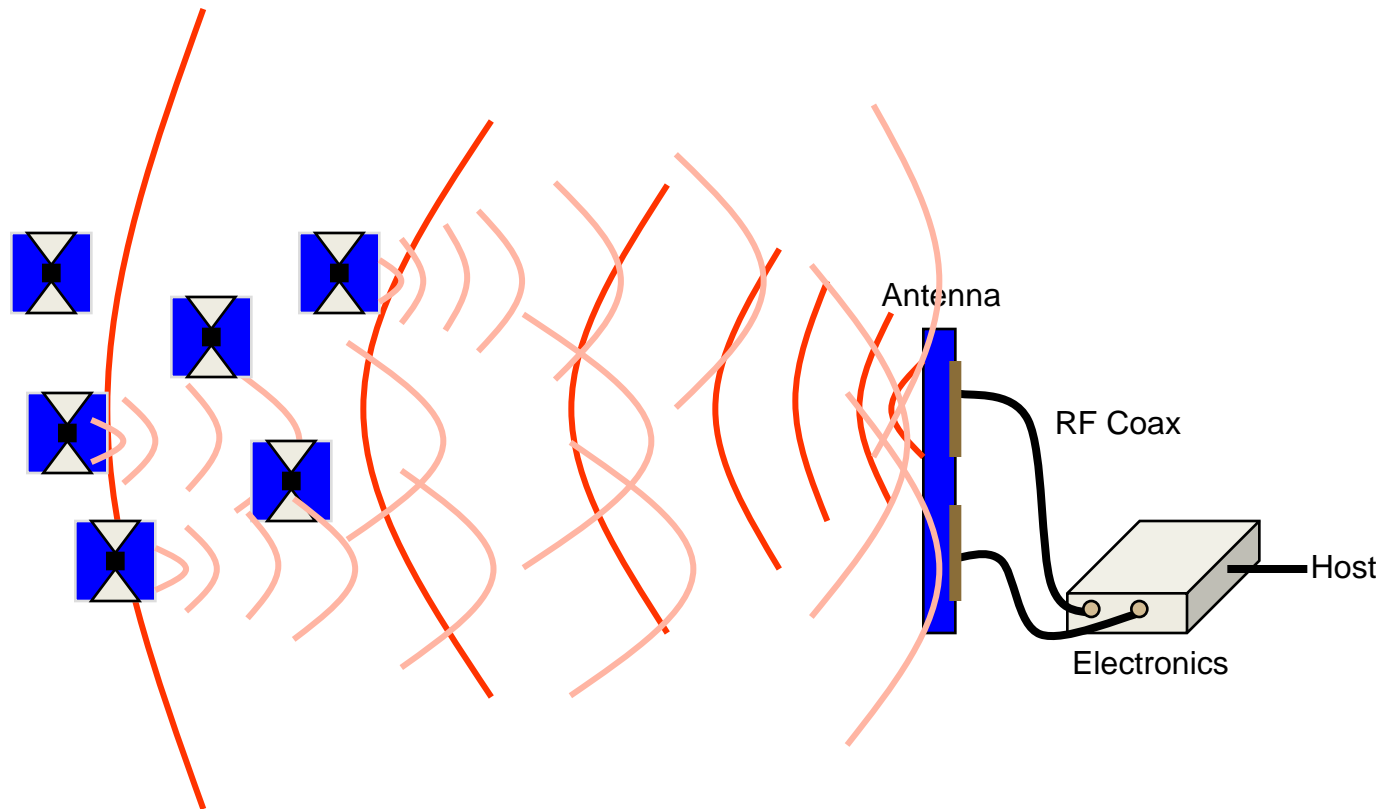
How Does Passive RFID Work?

Single Tag Communications



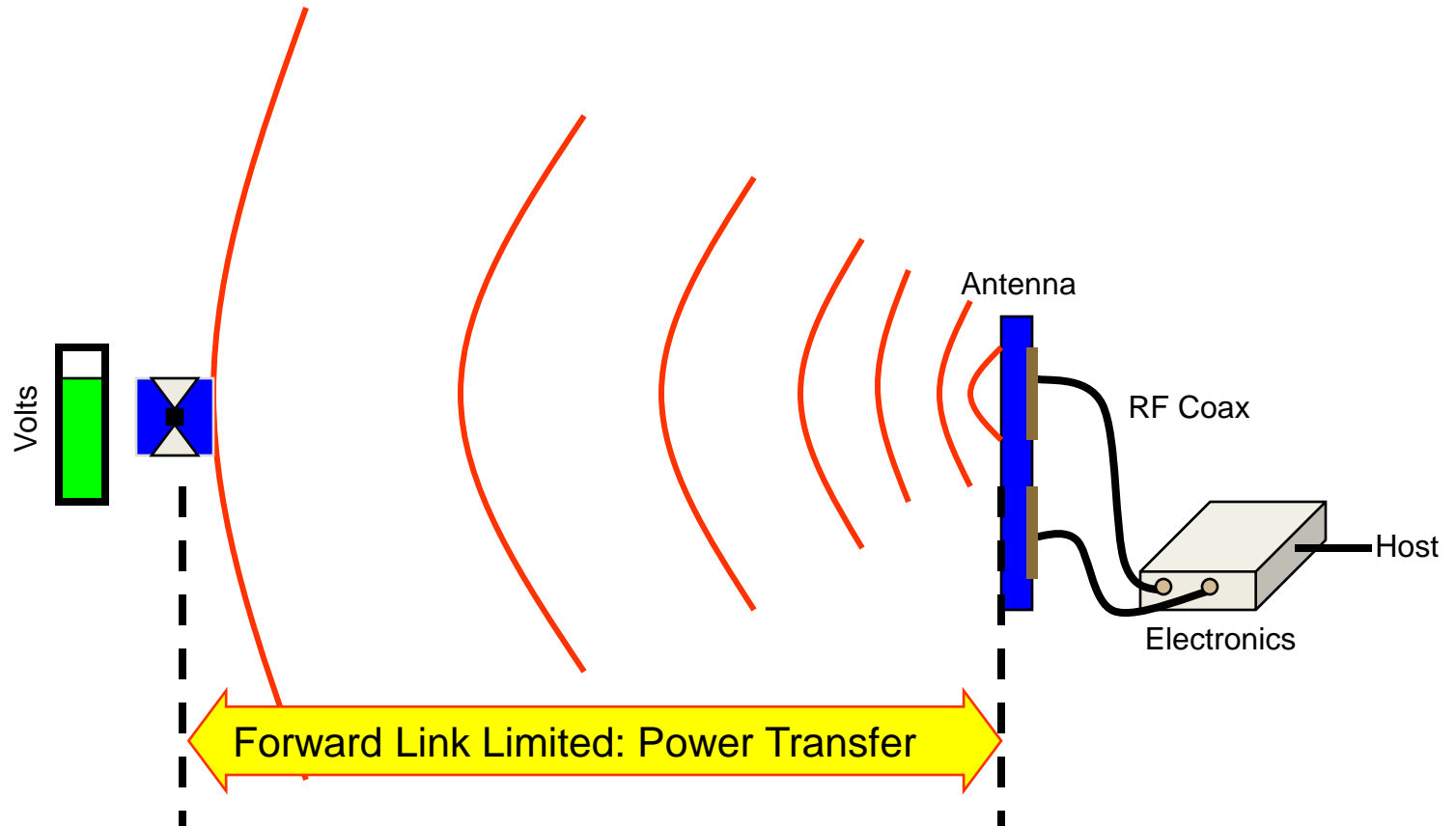
How Does Passive RFID Work?

Multiple Tag Communications



TDMA Tag 1 Tag 2 Tag 3 Tag 4 Tag 5 ○ ○ ○ Tag n

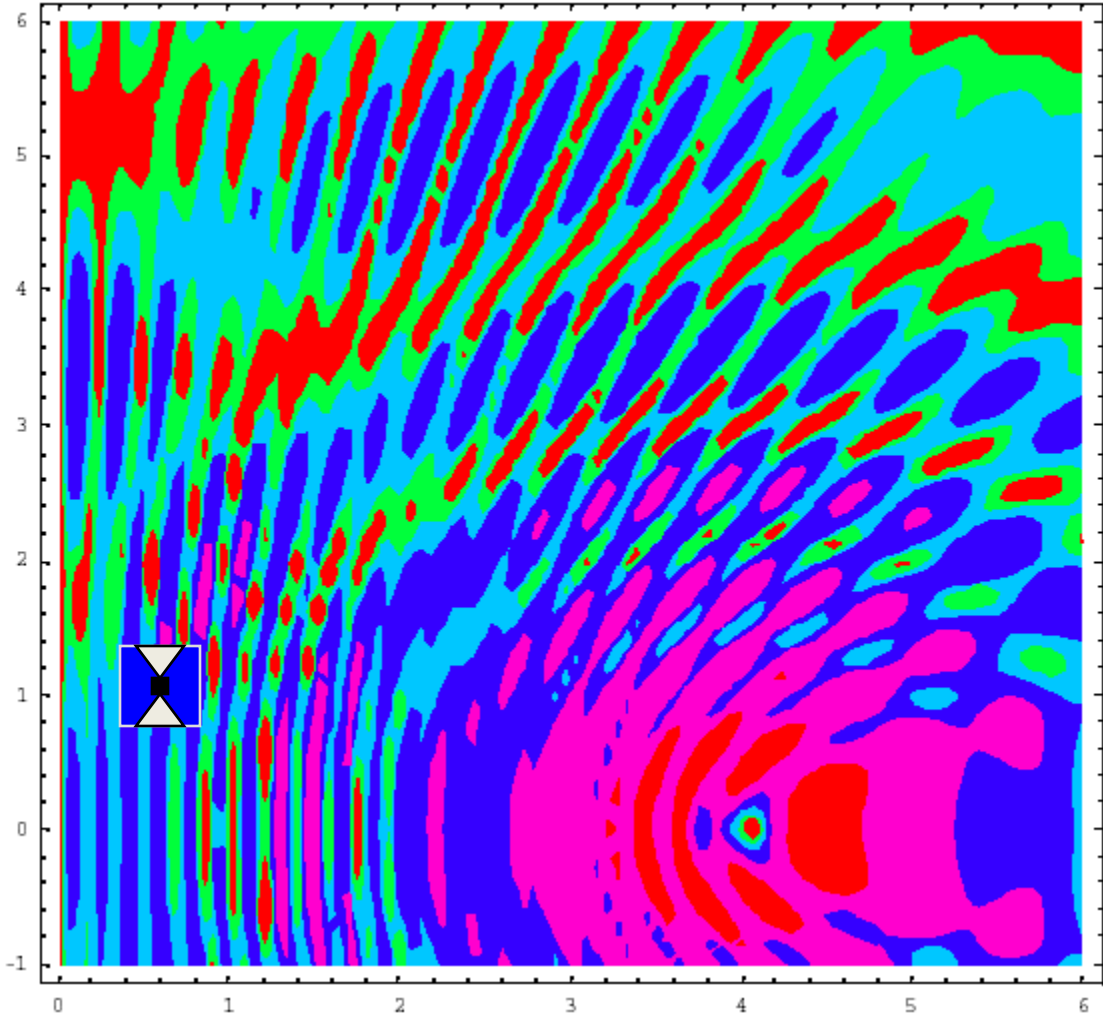
Maximum Range for Passive Tags



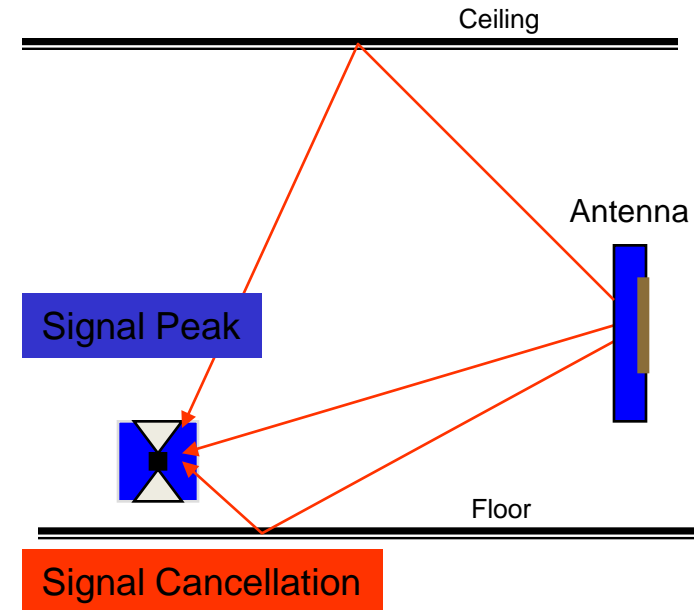
What are the real-world challenges?

Passive Tag Power Source is Unreliable

Power Distribution at 868 MHz

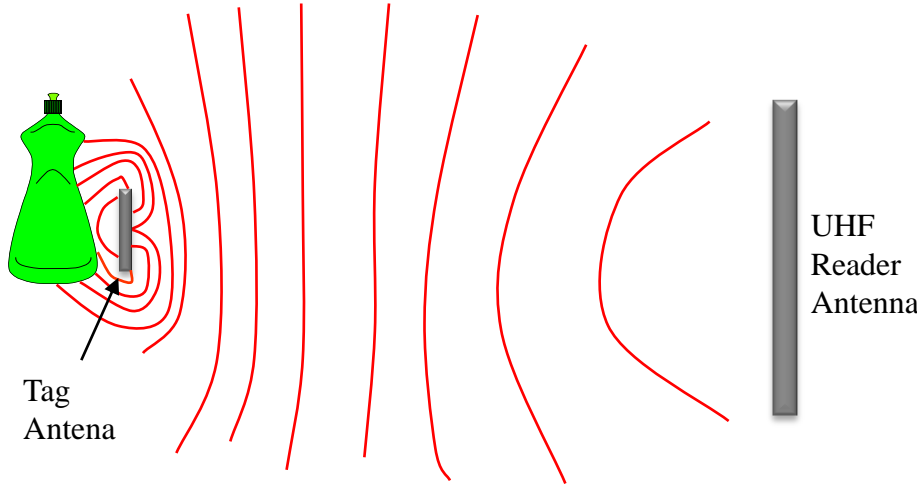


Palomar, Anu-Leena Annala, et al.

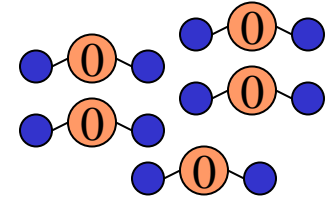


Energy Sinks and Shifts

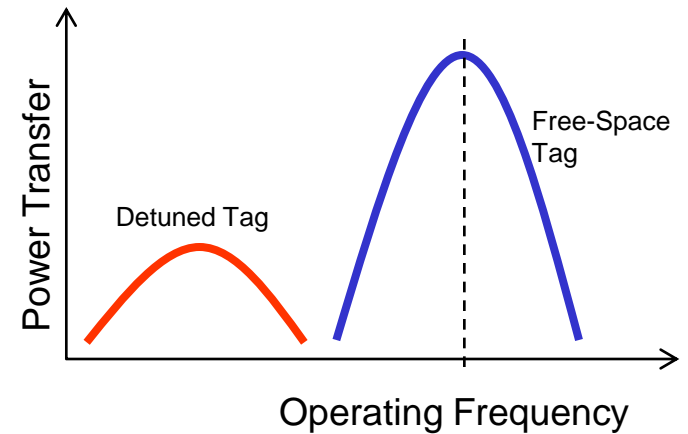
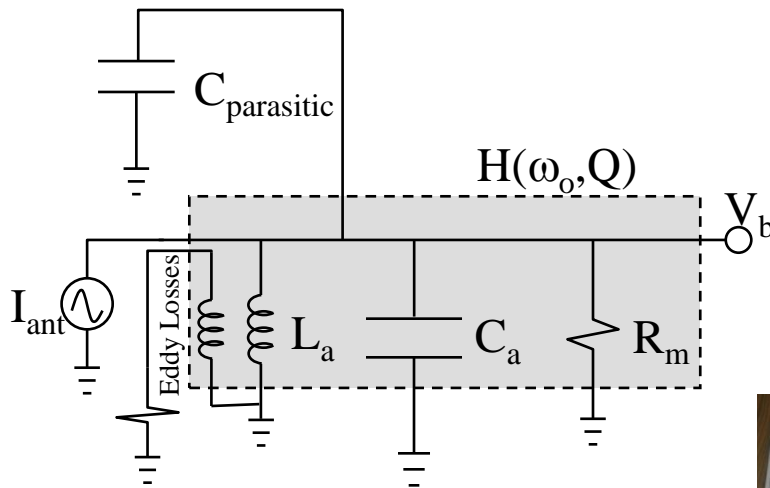
Liquids



H₂O Dipole Energy Absorption



Metals



An RFID Challenged Application

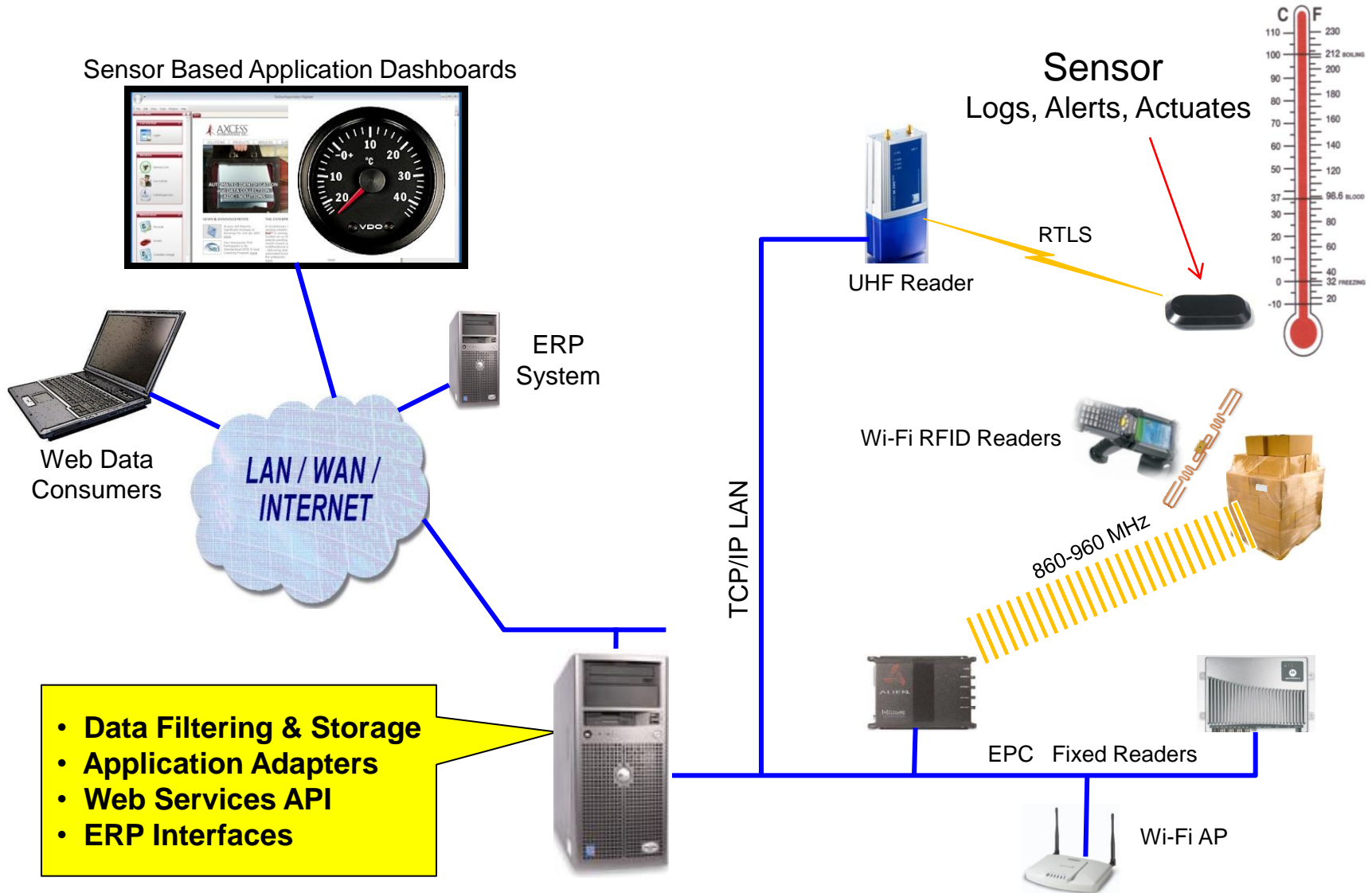


Tag Localization Challenge



How does RFID
work within a system?

Multi-Technology RFID System



Summary

- **RFID is an important technology in transportation**
 - **Electronic toll collection**
 - **Supply chain asset visibility**
 - **Emerging transportation markets**
 - **Combo transit pass, cashless payment, and access control**
 - **Real-time locating systems (RTLS)**
 - **Multi-modal asset tracking and condition monitoring**
 - **Product safety and security**
 - **No one RFID technology addresses all needs**
- **The technology must be deployed with care**
 - **Simple in concept, but complex in practice**
 - **Game changing potential if used wisely**

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