

RFID: Technology and Applications

Sridhar Iyer

IIT Bombay

sri@it.iitb.ac.in

www.it.iitb.ac.in/~sri



Outline

- Overview of RFID
 - Reader-Tag; Potential applications
- RFID Technology Internals
 - RF communications; Reader/Tag protocols
 - Middleware architecture; EPC standards
- RFID Business Aspects
- Security and Privacy
- Conclusion

Product Marketing - 75 years ago

You can have
any color,
as long as its
black !

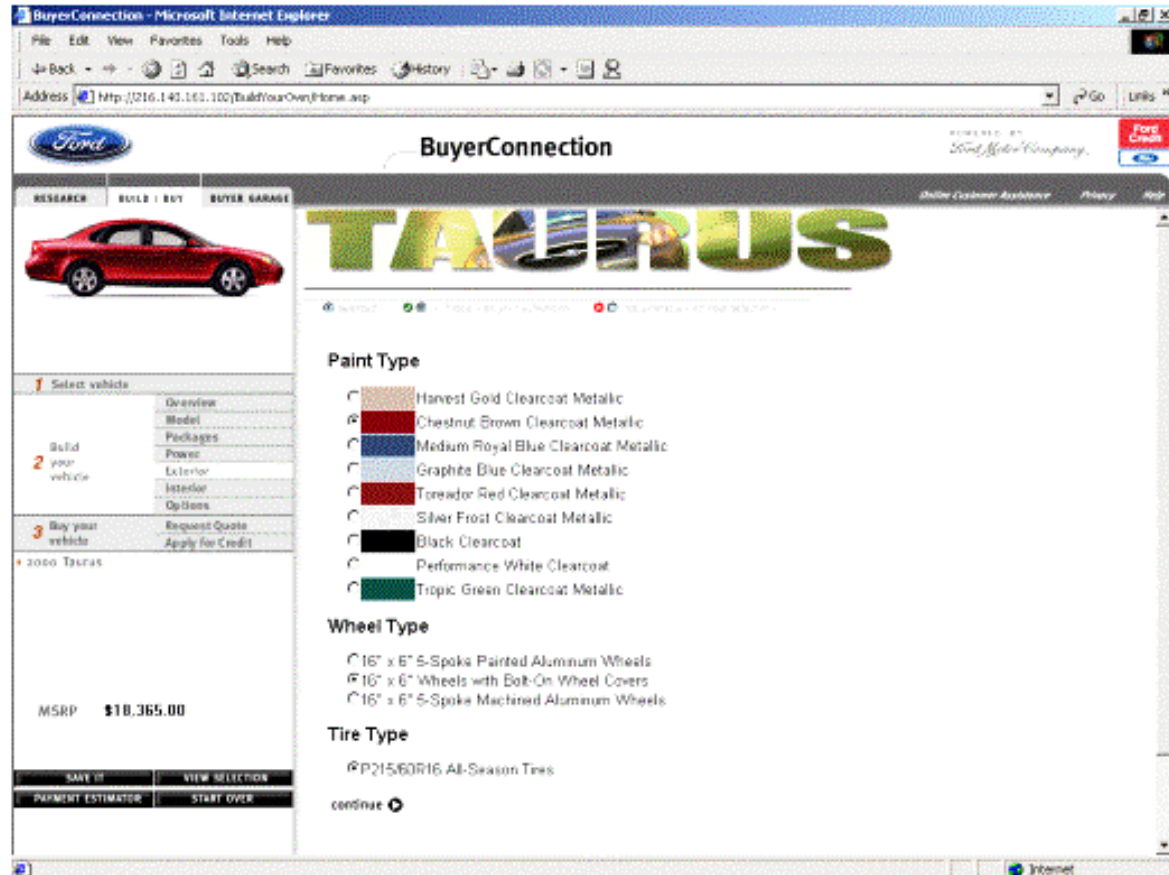


4

Product Marketing - Today

Add consumer flexibility, courtesy of robotics, computers ...

Customer window into final stage of manufacturing



Effect on manufacturing

- Need to ensure error-free, custom assembly
- Need inventory of components for the various customization options

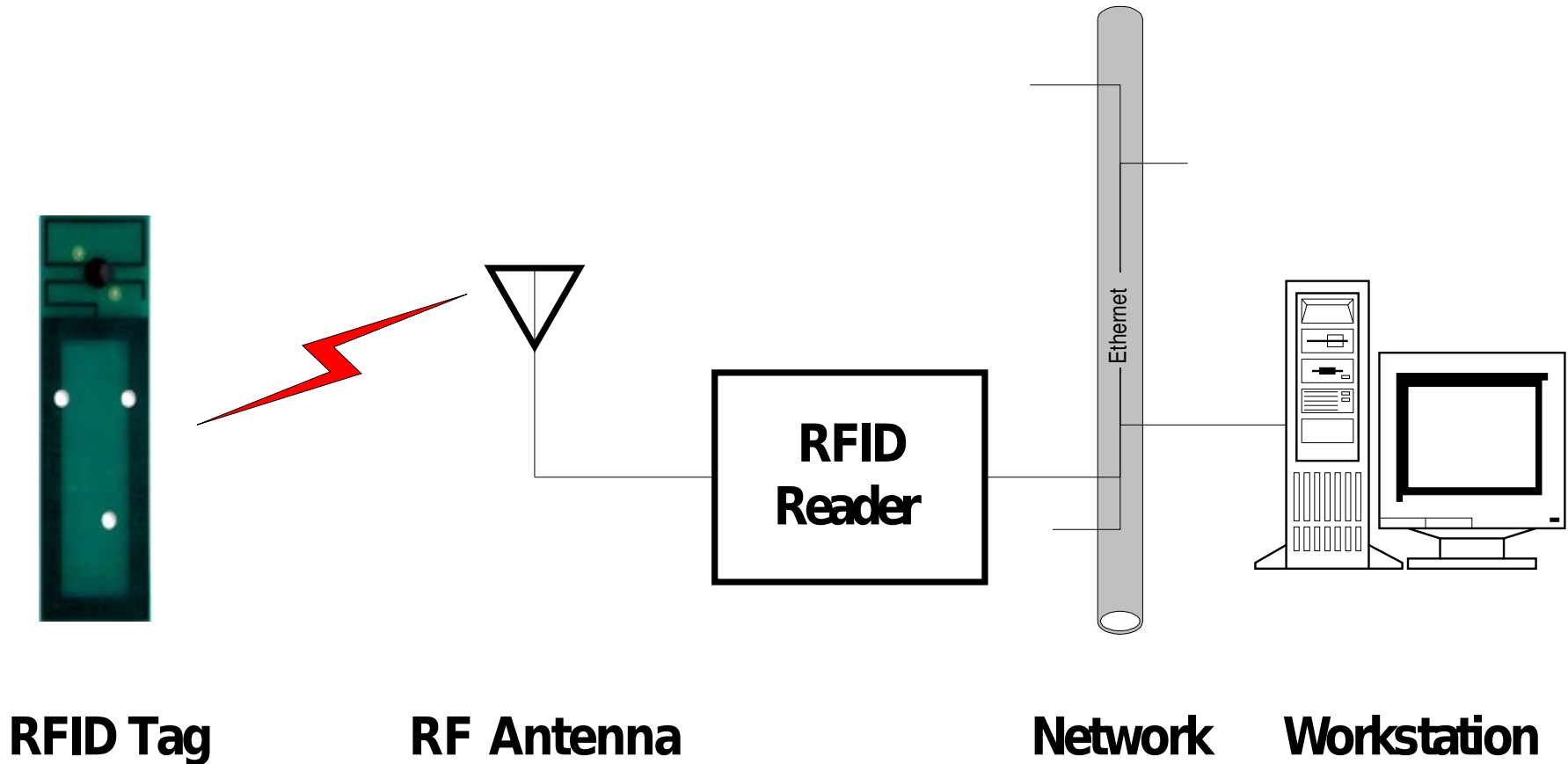
- Critical Issues
 - Assembly process control
 - Inventory management
 - Supply chain integration
 - Customer insight

- One solution: RFID

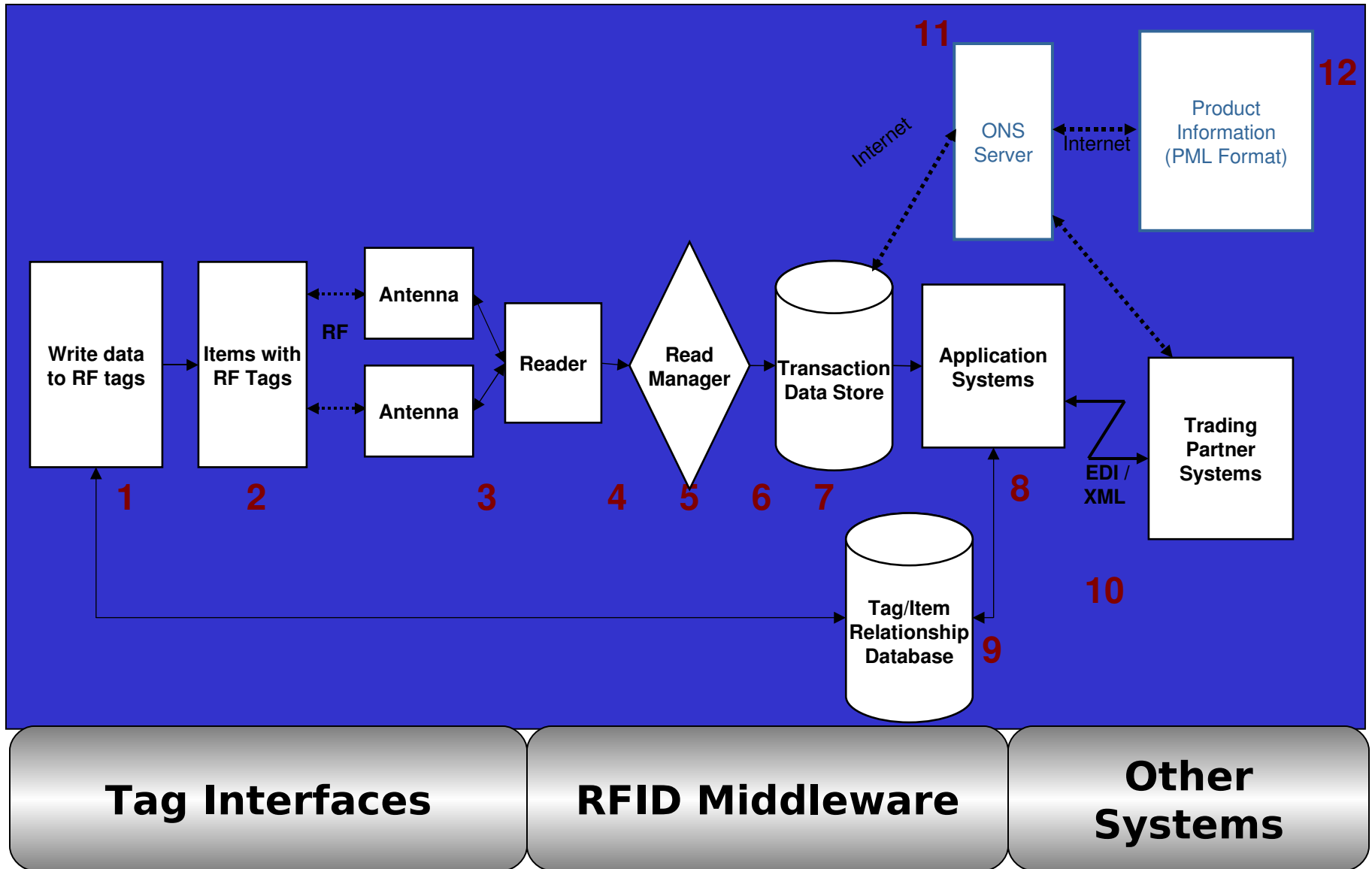
What is RFID?

- RFID = Radio Frequency IDentification.
- An ADC (Automated Data Collection) technology that:
 - uses radio-frequency waves to transfer data between a reader and a movable item to identify, categorize, track..
 - Is fast and does not require physical sight or contact between reader/scanner and the tagged item.
 - Performs the operation using low cost components.
 - Attempts to provide unique identification and backend integration that allows for wide range of applications.
- Other ADC technologies: Bar codes, OCR.

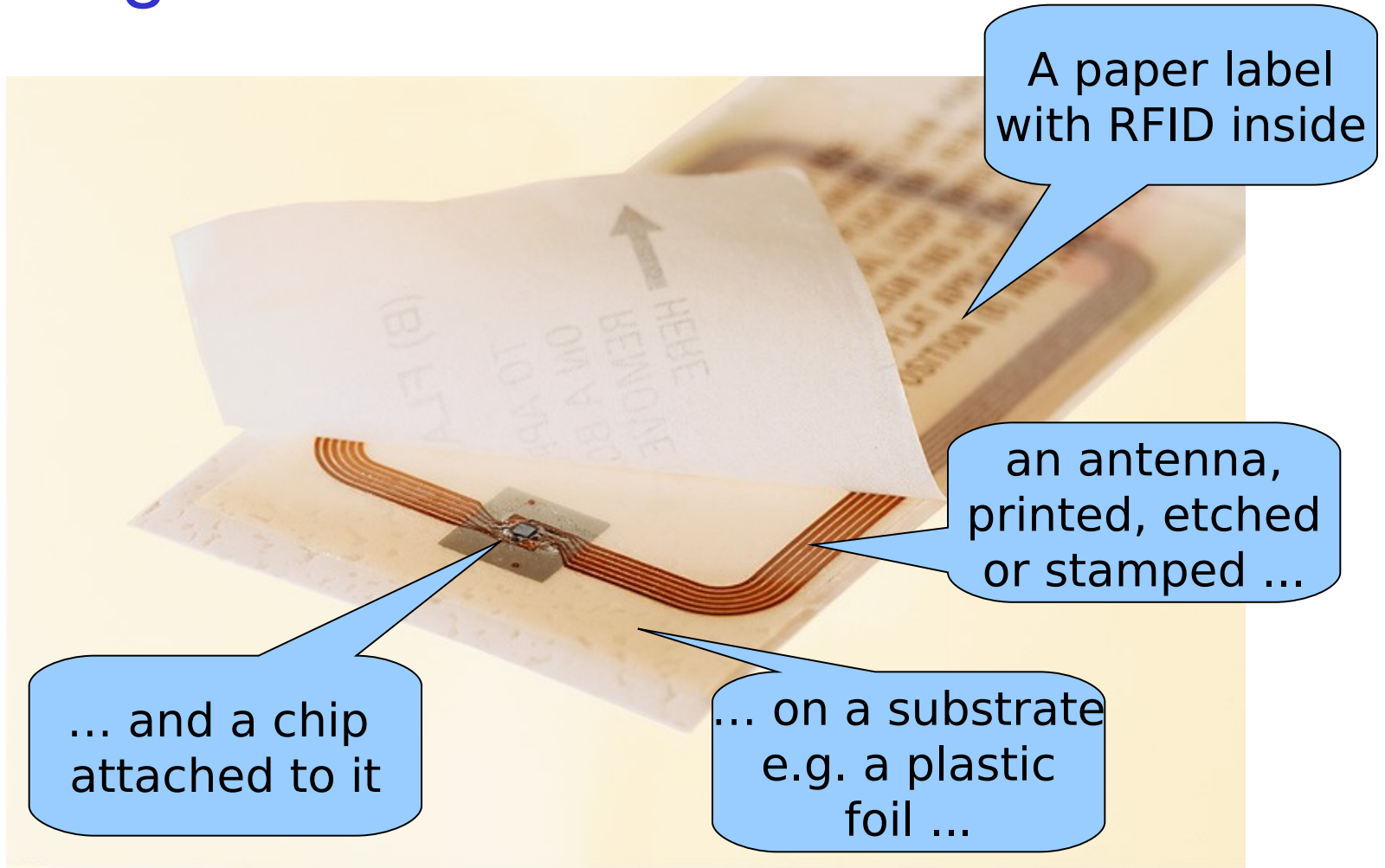
RFID system components



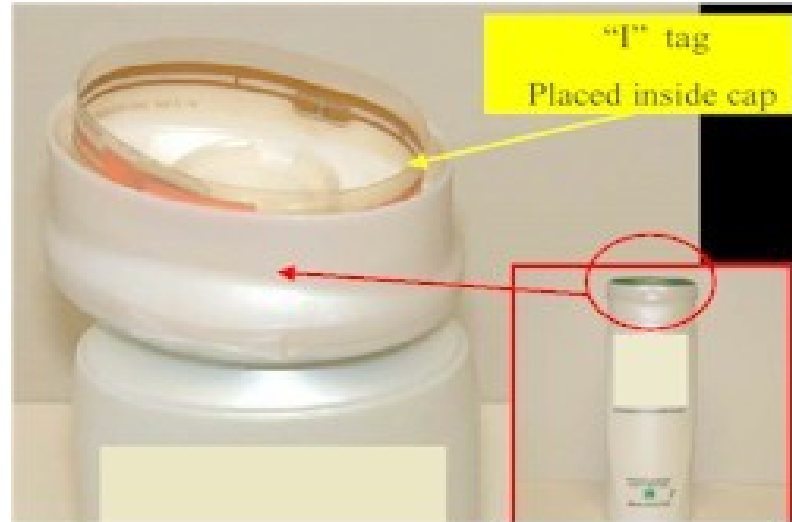
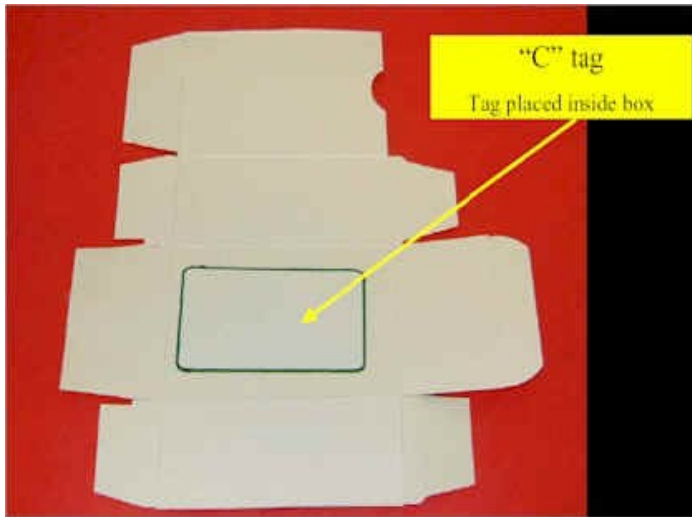
RFID systems: logical view



RFID tags: Smart labels



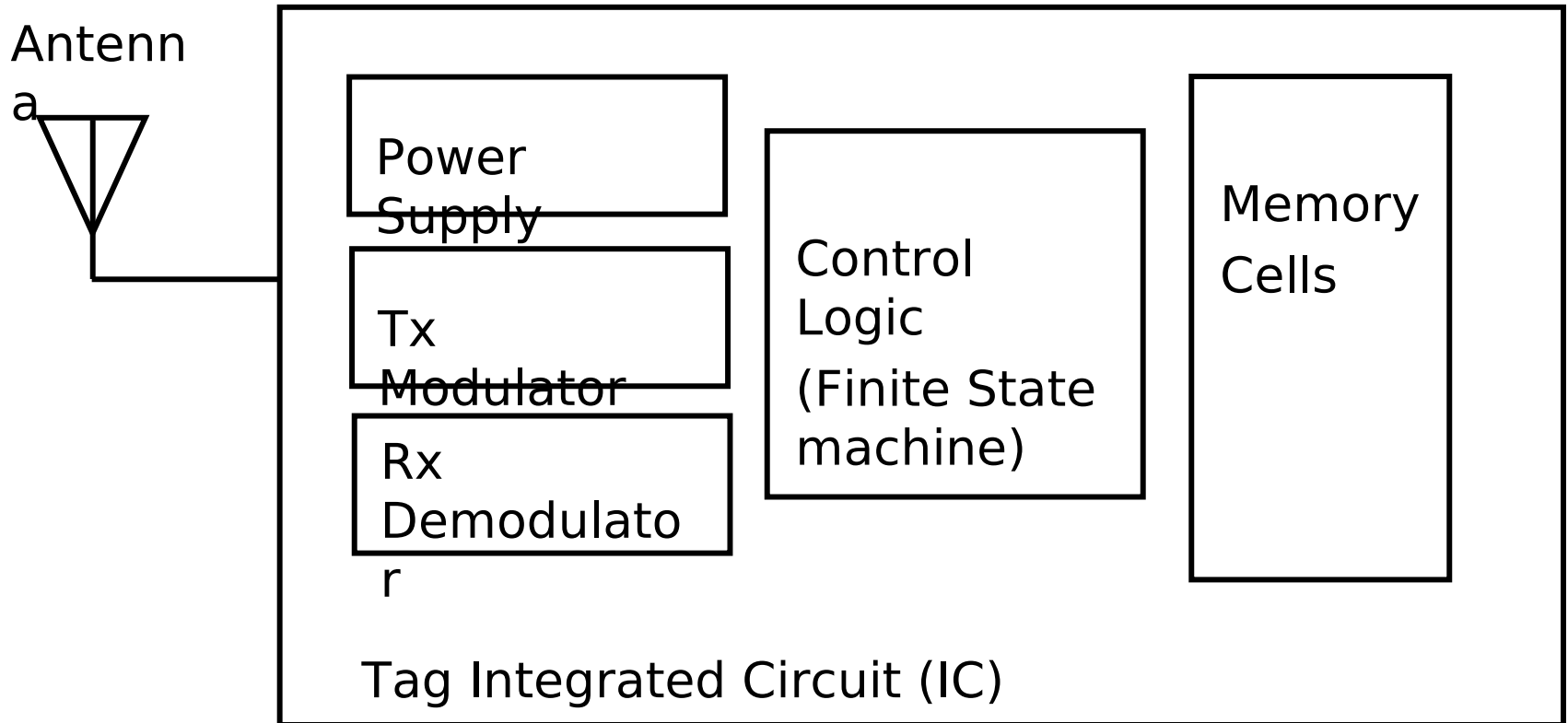
Some RFID tags



RFID tags

- Tags can be attached to almost anything:
 - Items, cases or pallets of products, high value goods
 - vehicles, assets, livestock or personnel
- **Passive Tags**
 - Do not require power – Draws from Interrogator Field
 - Lower storage capacities (few bits to 1 KB)
 - Shorter read ranges (4 inches to 15 feet)
 - Usually Write-Once-Read-Many/Read-Only tags
 - Cost around 25 cents to few dollars
- **Active Tags**
 - Battery powered
 - Higher storage capacities (512 KB)
 - Longer read range (300 feet)
 - Typically can be re-written by RF Interrogators
 - Cost around 50 to 250 dollars

Tag block diagram



RFID tag memory

- Read-only tags
 - Tag ID is assigned at the factory during manufacturing
 - Can never be changed
 - No additional data can be assigned to the tag
- Write once, read many (WORM) tags
 - Data written once, e.g., during packing or manufacturing
 - Tag is locked once data is written
 - Similar to a compact disc or DVD
- Read/Write
 - Tag data can be changed over time
 - Part or all of the data section can be locked

RFID readers

- Reader functions:
 - Remotely power tags
 - Establish a bidirectional data link
 - Inventory tags, filter results
 - Communicate with networked server(s)
 - Can read 100-300 tags per second
- Readers (interrogators) can be at a fixed point such as
 - Entrance/exit
 - Point of sale
- Readers can also be mobile/hand-held



Some RFID readers



F

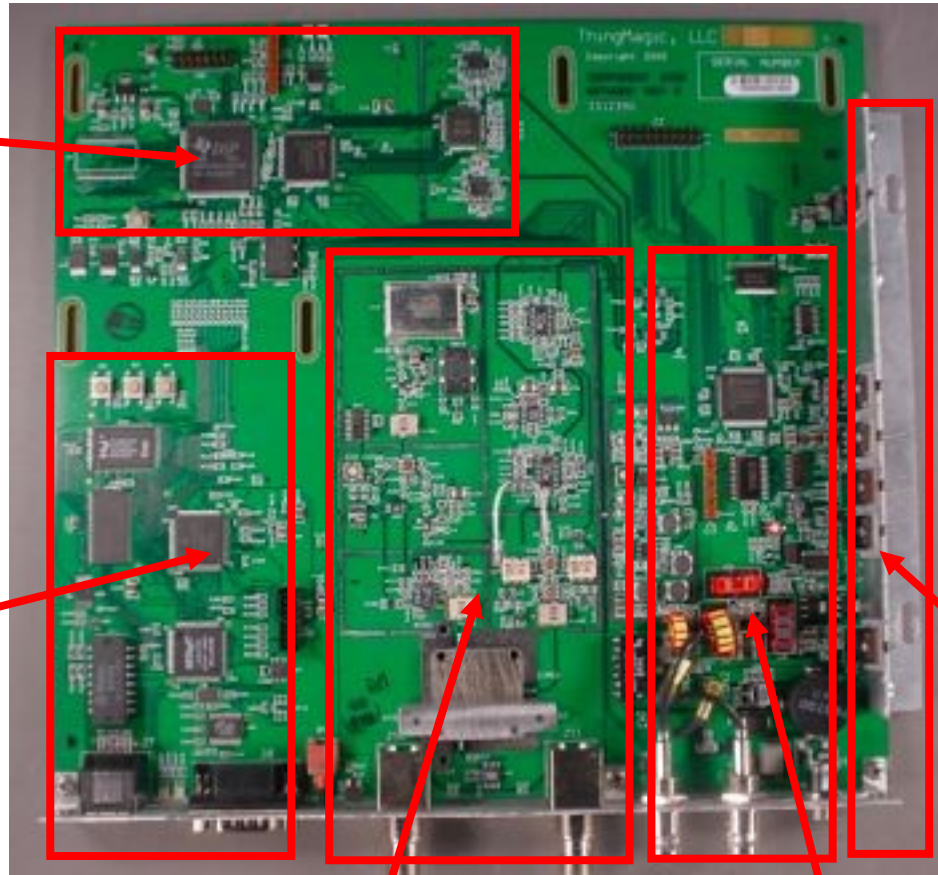
IIT Bombay

15
Source: www.buyrfid.org

Reader anatomy

Digital
Signal
Processor
(DSP)

Network
Processor



Power
Supply

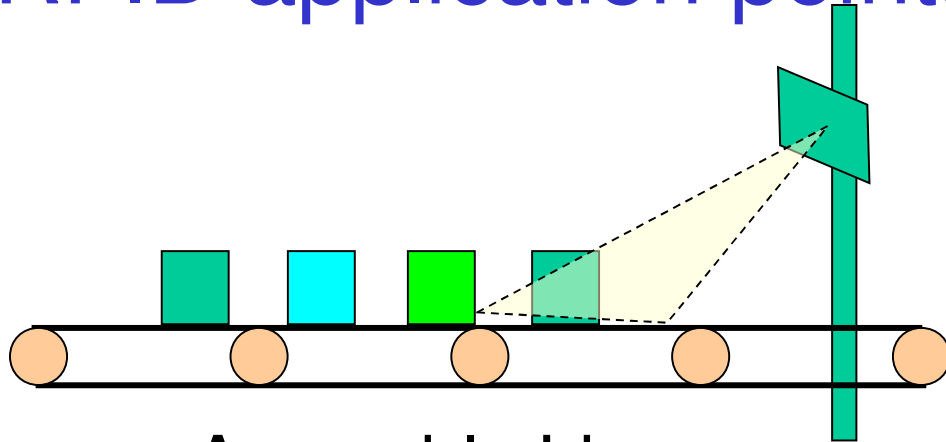
915MHz

Radio

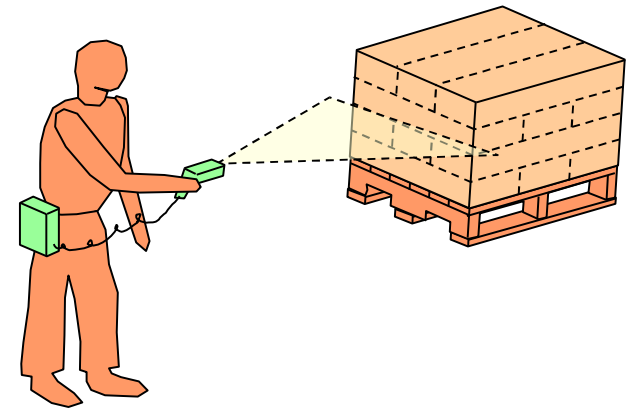
13.56MH

Z
Radio

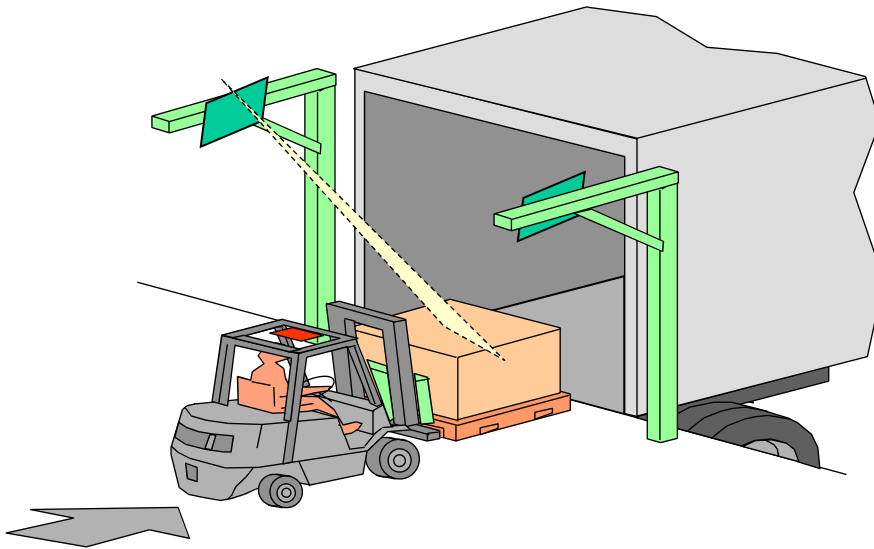
RFID application points



■ Assembly Line



■ Handheld Applications



■ Shipping Portals

RFID applications

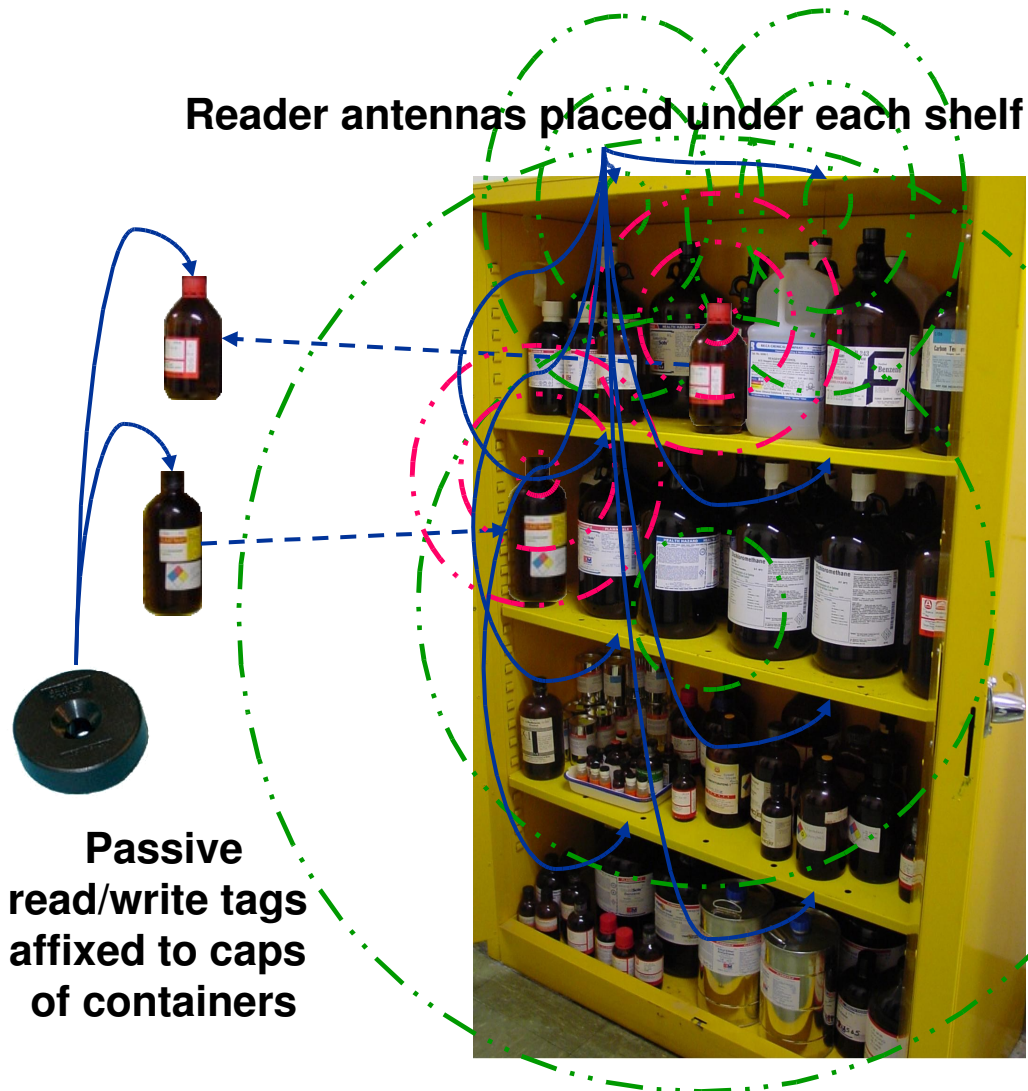
- Manufacturing and Processing
 - Inventory and production process monitoring
 - Warehouse order fulfillment
- Supply Chain Management
 - Inventory tracking systems
 - Logistics management
- Retail
 - Inventory control and customer insight
 - Auto checkout with reverse logistics
- Security
 - Access control
 - Counterfeiting and Theft control/prevention
- Location Tracking
 - Traffic movement control and parking management
 - Wildlife/Livestock monitoring and tracking

Smart groceries

- Add an RFID tag to all items in the grocery.
- As the cart leaves the store, it passes through an RFID transceiver.
- The cart is rung up in seconds.



Smart cabinet



1. Tagged item is removed from or placed in “Smart Cabinet”
1. “Smart Cabinet” periodically interrogates to assess inventory
1. Server/Database is updated to reflect item’s disposition
1. Designated individuals are notified regarding items that need attention (cabinet and shelf location, action required)

Smart fridge

- Recognizes what's been put in it
- Recognizes when things are removed
- Creates automatic shopping lists
- Notifies you when things are past their expiration

- Shows you the recipes that most closely match what is available

Smart groceries enhanced

- Track products through their entire lifetime.



Some more smart applications

- “Smart” appliances:
 - Closets that advice on style depending on clothes available.
 - Ovens that know recipes to cook pre-packaged food.
- “Smart” products:
 - Clothing, appliances, CDs, etc. tagged for store returns.
- “Smart” paper:
 - Airline tickets that indicate your location in the airport.
- “Smart” currency:
 - Anti-counterfeiting and tracking.
- “Smart” people ??

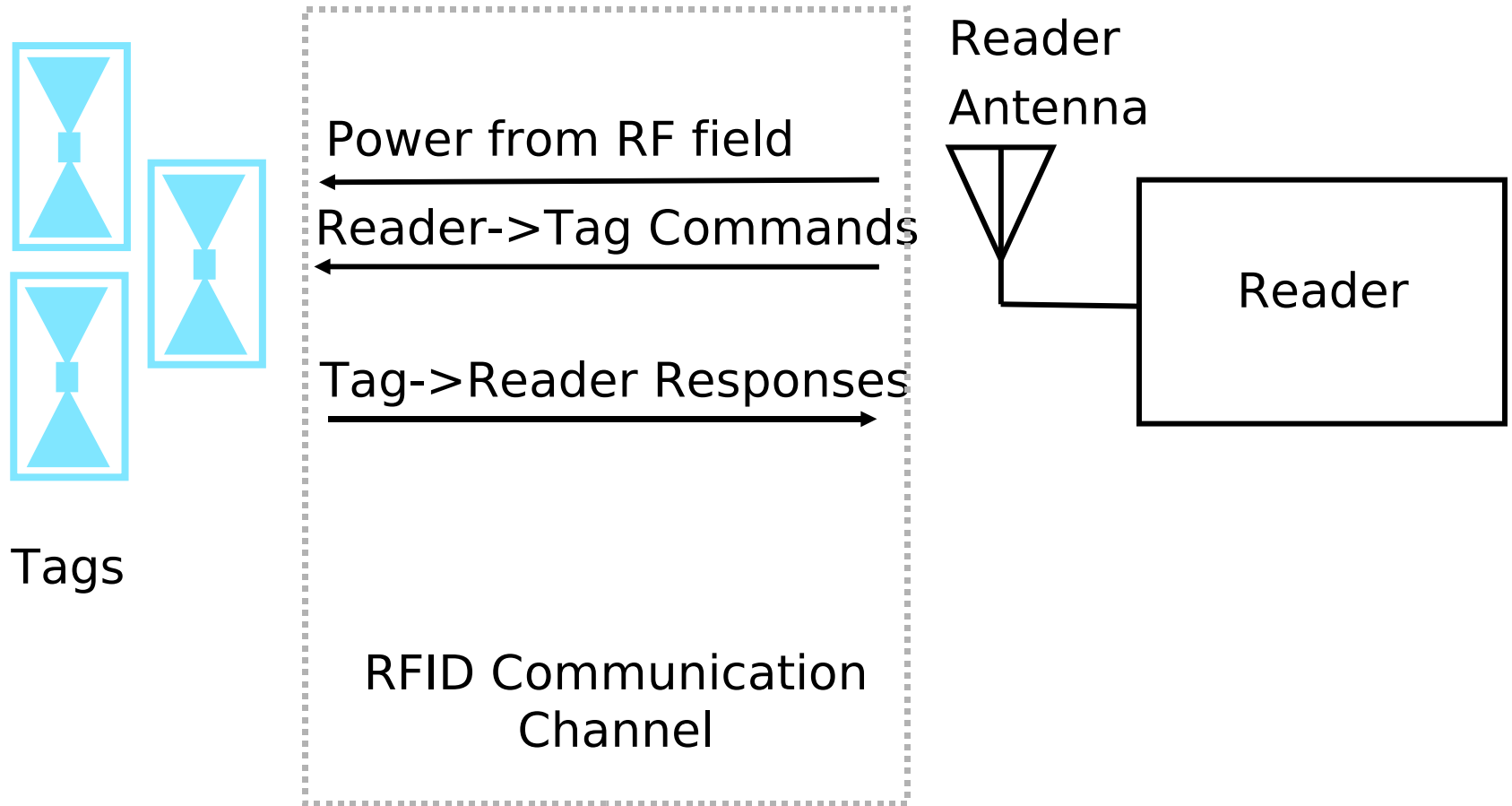
RFID advantages over bar-codes

- No line of sight required for reading
- Multiple items can be read with a single scan
- Each tag can carry a lot of data (read/write)
- Individual items identified and not just the category
- Passive tags have a virtually unlimited lifetime
- Active tags can be read from great distances
- Can be combined with barcode technology

Outline

- Overview of RFID
 - Reader-Tag; Potential applications
- **RFID Technology Internals**
 - RF communications; Reader/Tag protocols
 - Middleware architecture; EPC standards
- RFID Business Aspects
- Security and Privacy
- Conclusion

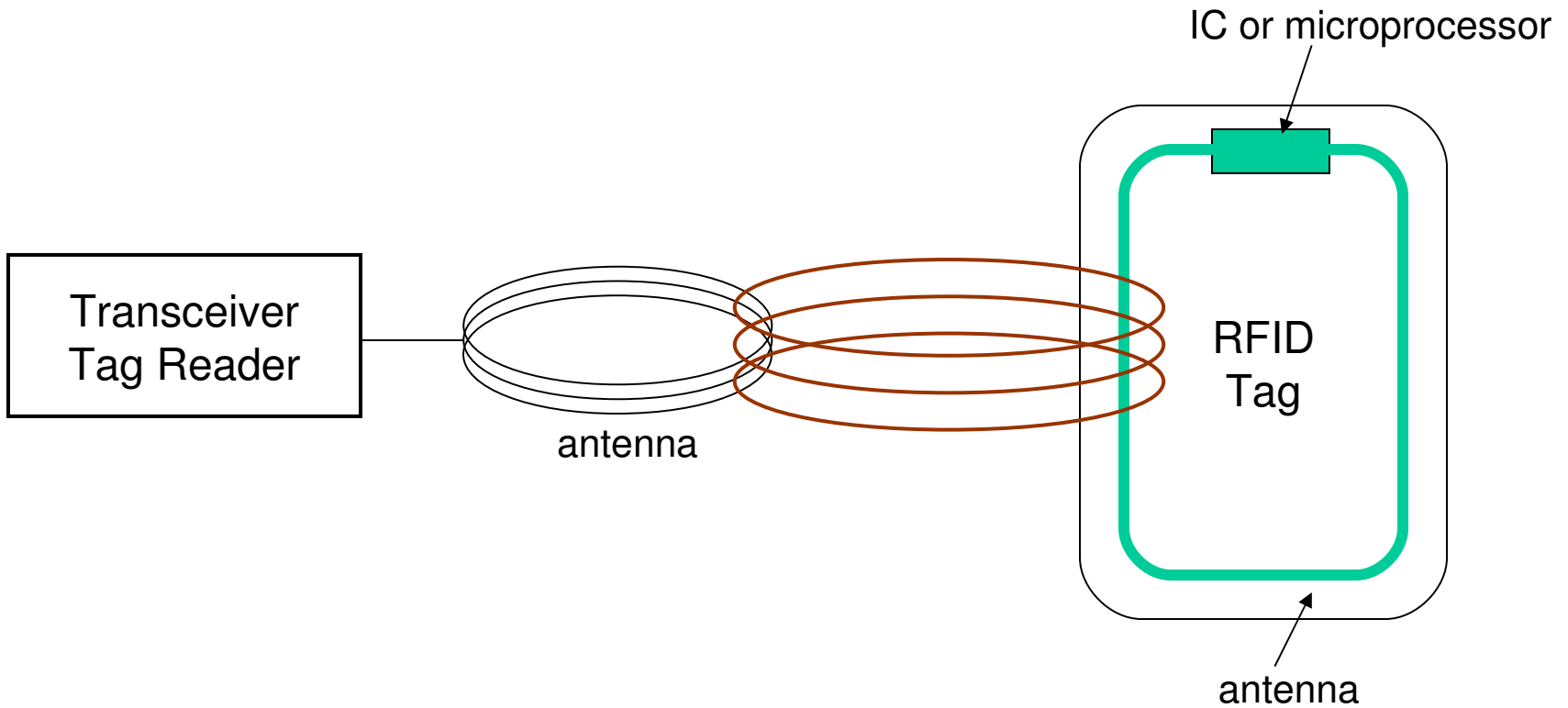
RFID communications



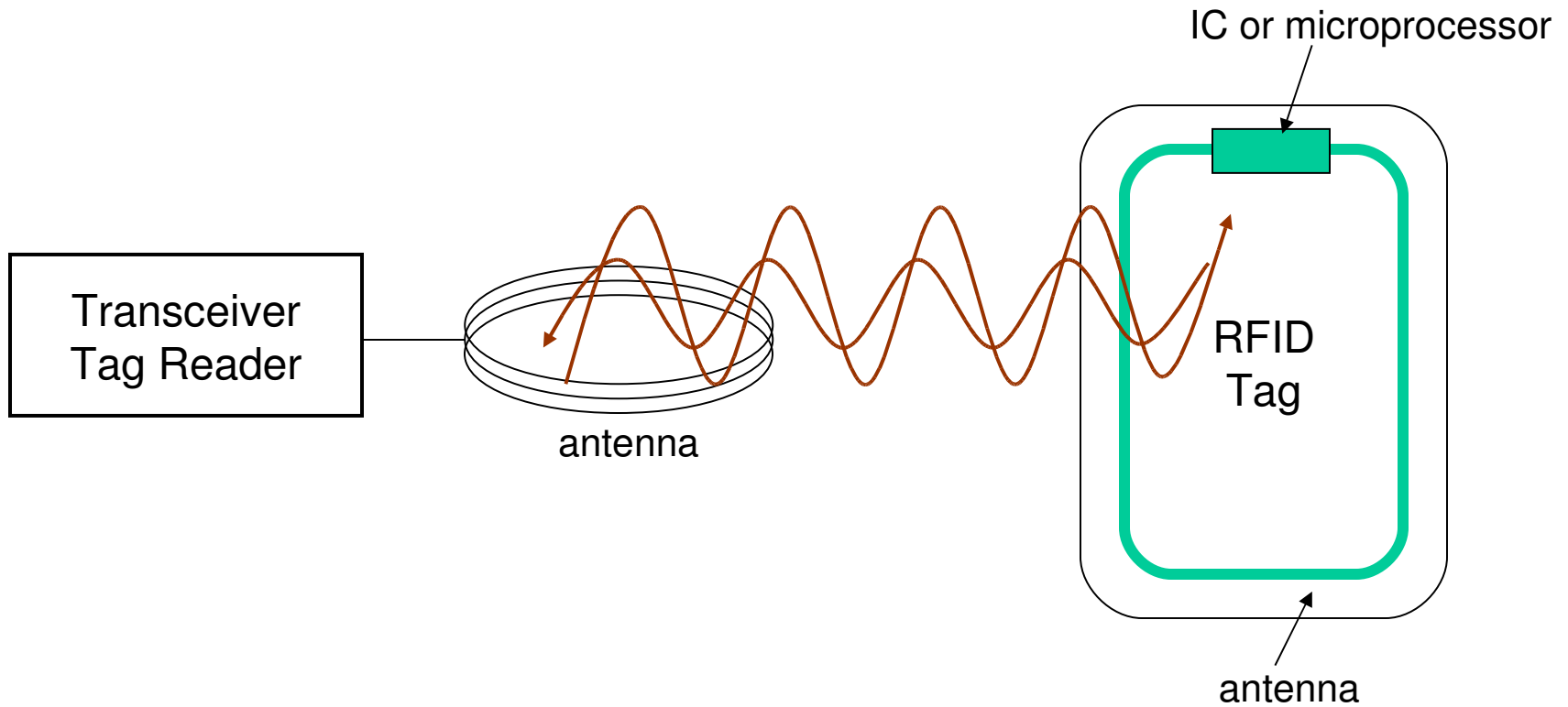
RFID communication

- Host manages Reader(s) and issues Commands
- Reader and tag communicate via RF signal
- Carrier signal generated by the reader
- Carrier signal sent out through the antennas
- Carrier signal hits tag(s)
- Tag receives and modifies carrier signal
 - “sends back” modulated signal (Passive Backscatter – also referred to as “field disturbance device”)
- Antennas receive the modulated signal and send them to the Reader
- Reader decodes the data
- Results returned to the host application

Antenna fields: Inductive coupling



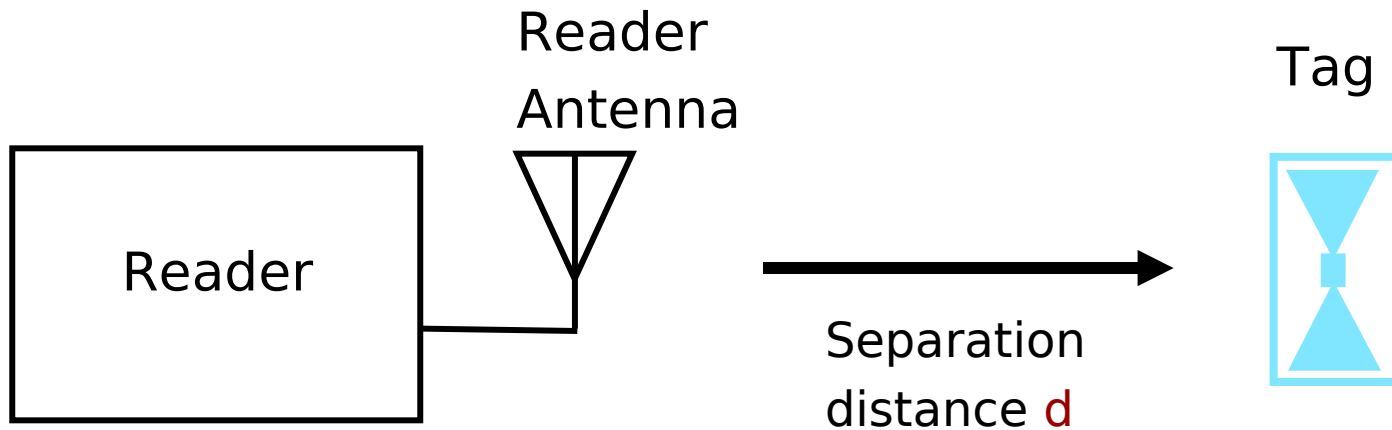
Antenna fields: Propagation coupling



Operational frequencies

Frequency Ranges	LF 125 KHz	HF 13.56 MHz	UHF 868 - 915 MHz	Microwave 2.45 GHz & 5.8 GHz
Typical Max Read Range (Passive Tags)	Shortest 1''-12''	Short 2''-24''	Medium 1'-10'	Longest 1'-15'
Tag Power Source	Generally passive tags only, using inductive coupling	Generally passive tags only, using inductive or capacitive coupling	Active tags with integral battery or passive tags using capacitive storage, E-field coupling	Active tags with integral battery or passive tags using capacitive storage, E-field coupling
Data Rate	Slower	Moderate	Fast	Faster
Ability to read near metal or wet surfaces	Better	Moderate	Poor	Worse
Applications	Access Control & Security Identifying widgets through manufacturing processes or in harsh environments Ranch animal identification Employee IDs	Library books Laundry identification Access Control Employee IDs	supply chain tracking Highway toll Tags	Highway toll Tags Identification of private vehicle fleets in/out of a yard or facility Asset tracking

Reader->Tag power transfer



Q: If a reader transmits P_r watts, how much power P_t does the tag receive at a separation distance d ?

A: It depends-

UHF (915MHz) : Far field propagation : $P_t \propto 1/d^2$

HF (13.56MHz) : Inductive coupling : $P_t \propto 1/d^6$

Limiting factors for passive RFID

1. Reader transmitter power P_r (Gov't. limited)
2. Reader receiver sensitivity S_r
3. Reader antenna gain G_r (Gov't. limited)
4. Tag antenna gain G_t (Size limited)
5. Power required at tag P_t (Silicon process limited)
6. Tag modulator efficiency E_t

Implications

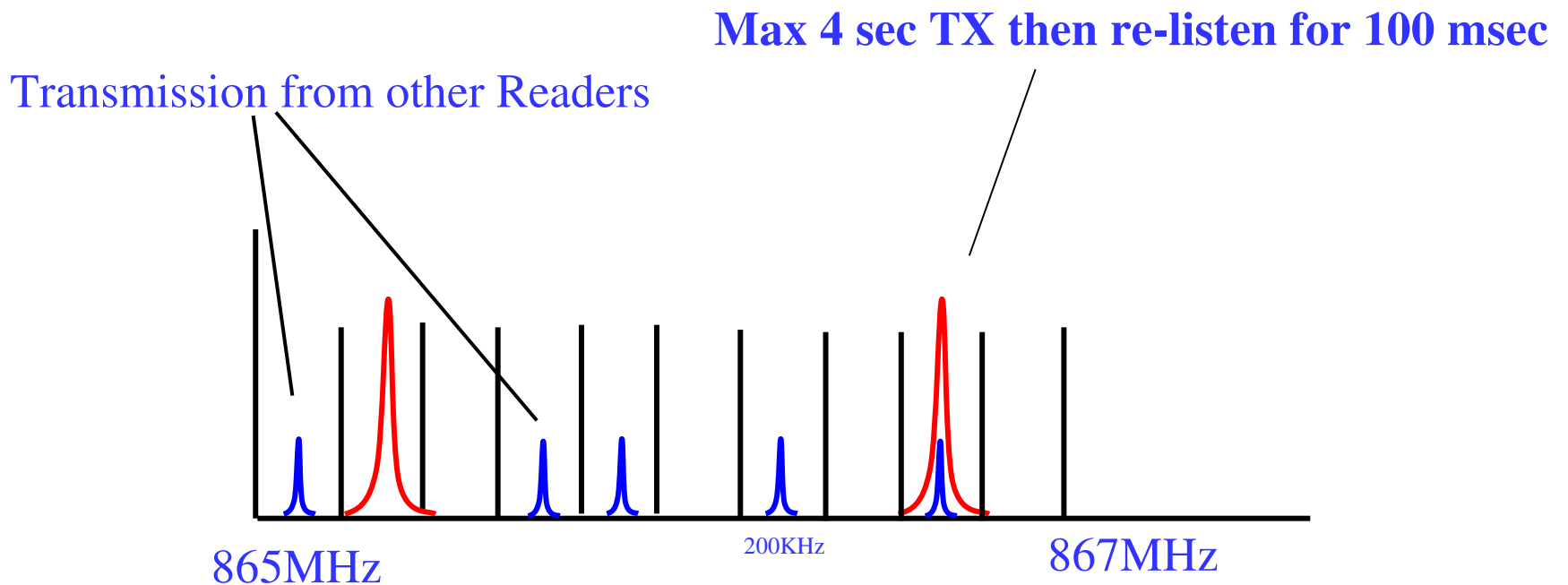
- Since $P_t \propto 1/d^2$, doubling read range requires 4X the transmitter power.
- Larger antennas can help, but at the expense of larger physical size because $G\{t,r\} \propto \text{Area}$.
- More advanced CMOS process technology will help by reducing P_t .
- At large distances, reader sensitivity limitations dominate.

RF effects of common materials

Material	Effect(s) on RF signal
Cardboard	Absorption (moisture) Detuning (dielectric)
Conductive liquids (shampoo)	Absorption
Plastics	Detuning (dielectric)
Metals	Reflection
Groups of cans	Complex effects (lenses, filters) Reflection
Human body / animals	Absorption, Detuning, Reflection

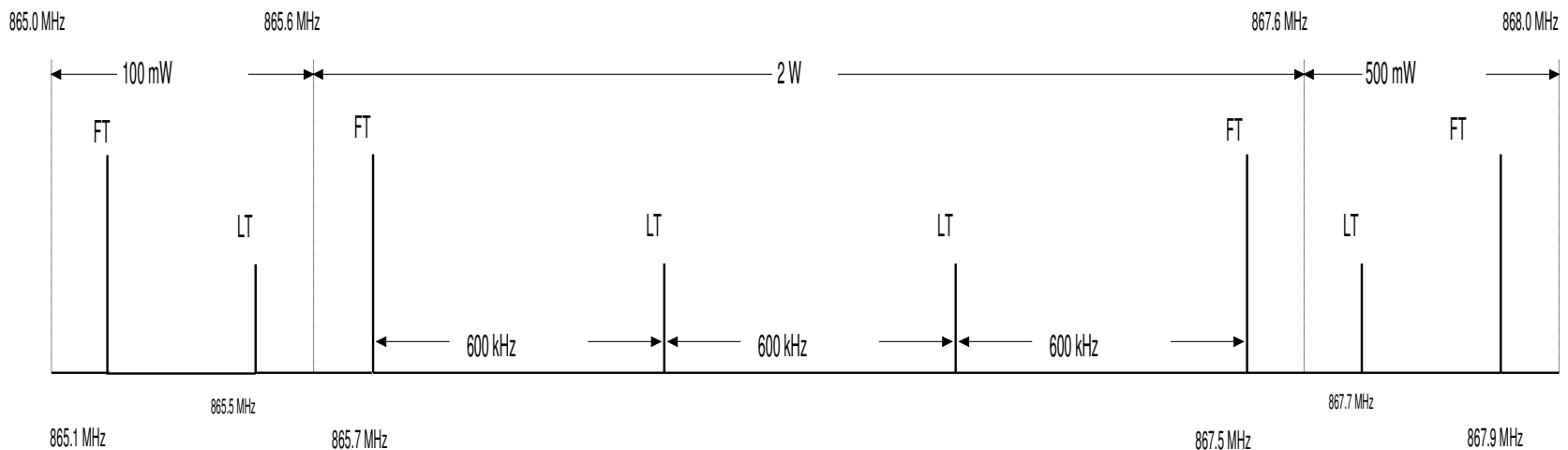
Communication protocols

- Listen before talk
- Mandatory listen time of >5 msec before each transmission



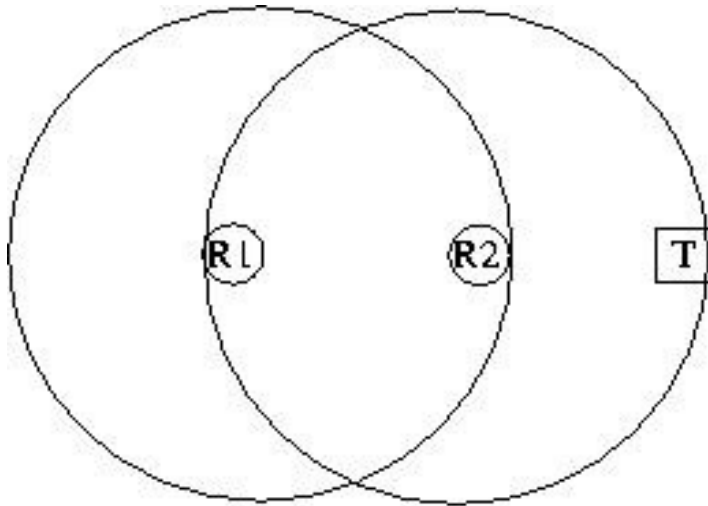
ETSI EN 302 208 standard

- Shared operation in band 865.0 – 868.0 MHz at transmit powers upto 2 W ERP.
 - Operation in 10 sub-bands of 200 kHz.
 - Power levels of 100 mW, 500 mW and 2 W ERP.
- Mandatory “listen before talk” and “look before leap”.

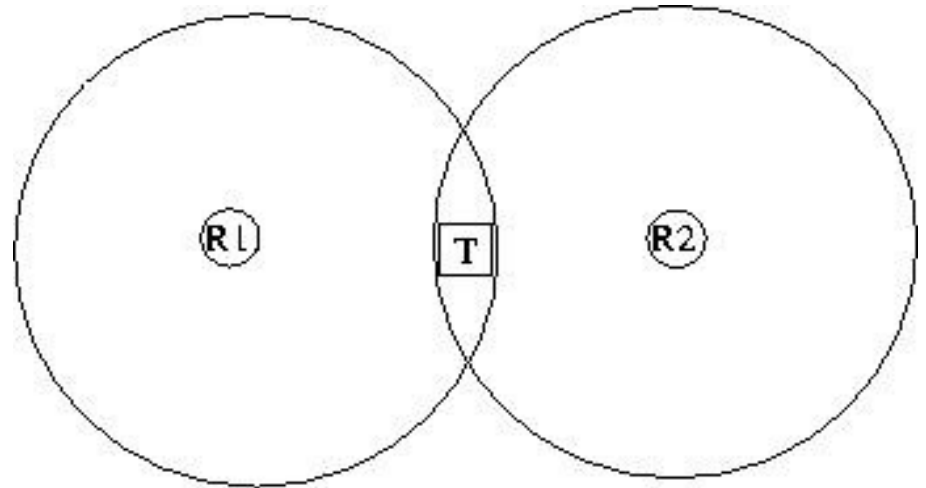


Reader Collision Problem

- Reader-Reader Interference
- Reader-Tag Interference



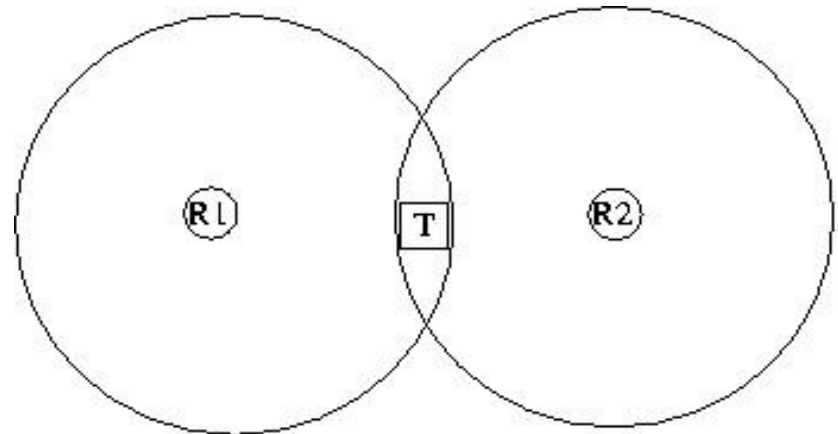
Reader to Reader Interference



Reader to Tag Interference

Reader Collision and Hidden Terminal

- The passive tags are not able to take part in the collision resolution or avoidance, as in other wireless systems
- Consider: RTS-CTS for hidden terminal problem in 802.11
 - rfid: T is not able to send a CTS in response to an RTS from R
- In case multiple readers try to read the same tag, the tag cannot respond selectively to a particular reader



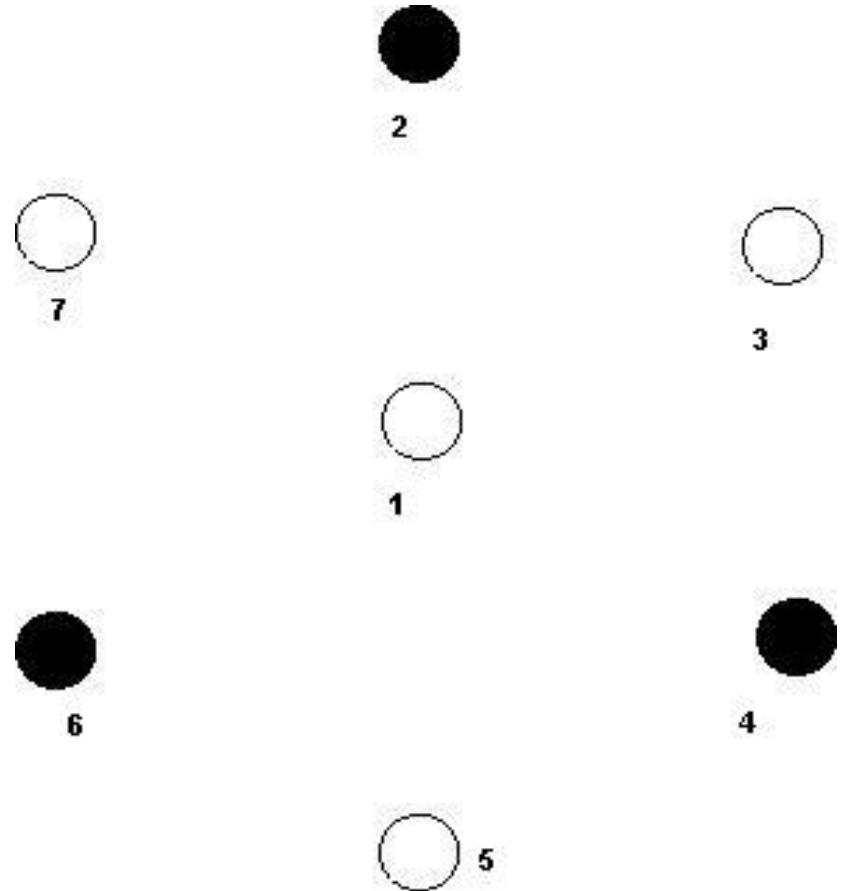
R2 is a hidden terminal for R1 – T communication

TDMA based solution

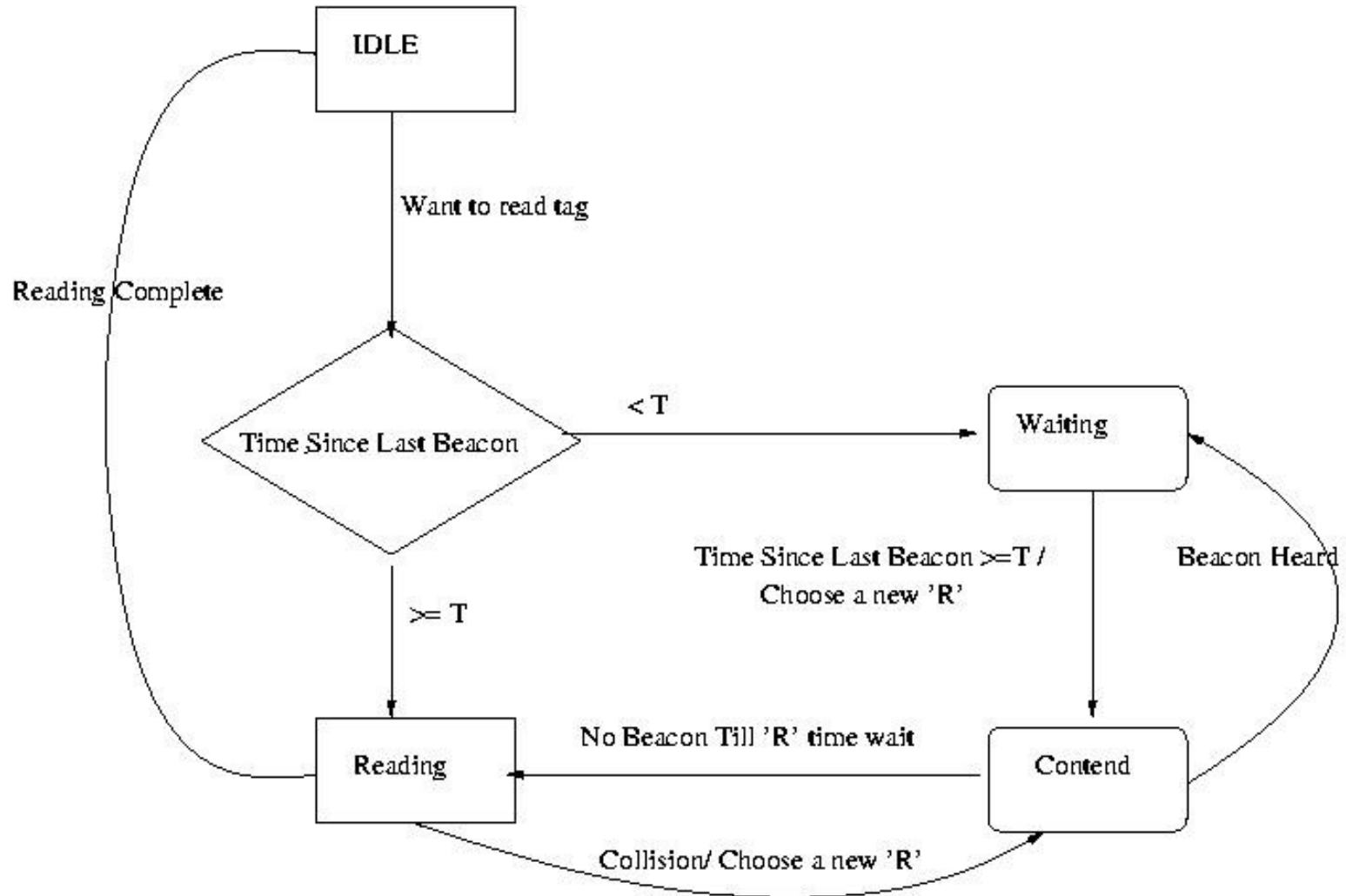
- Assign different time slots and/or frequencies to nearby readers
 - Reduces to graph coloring problem (readers form vertices)
- Only reader to reader interference
 - Assign different operating frequencies
- Only multiple reader to tag interference
 - Assign different time slots for operation
- Both types of interference
 - First allot different time slots, then frequencies

Beacon based solution

- A reader while reading tag, periodically sends a beacon on the control channel
- Assumptions
 - Separate control channel between readers
 - The range in the control channel is sufficient for a reader to communicate with all the possible readers that might interfere in the data channel



Beacon based solution (contd.)



Multiple Tags

When multiple tags are in range of the reader:

- All the tags will be excited at the same time.
- Makes it very difficult to distinguish between the tags.

Collision avoidance mechanisms:

- Probabilistic:
 - Tags return at random times.
- Deterministic:
 - Reader searches for specific tags.

Tag Collision Problem

- Multiple tags simultaneously respond to query
 - Results in collision at the reader

- Several approaches
 - Tree algorithm
 - Memoryless protocol
 - Contactless protocol
 - I-code protocol

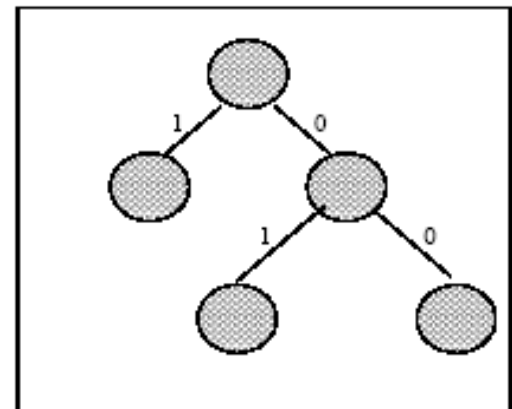
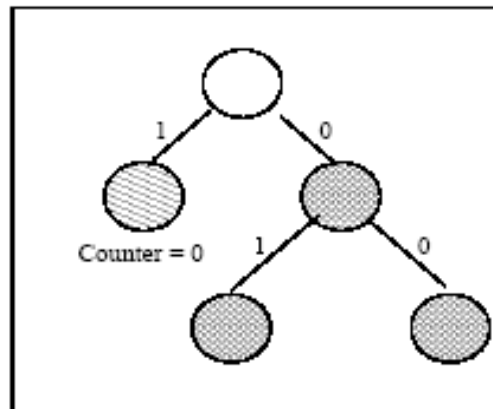
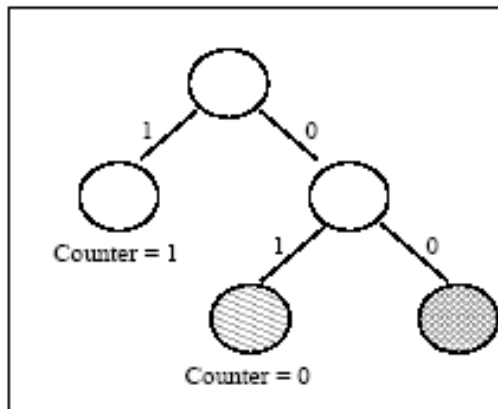
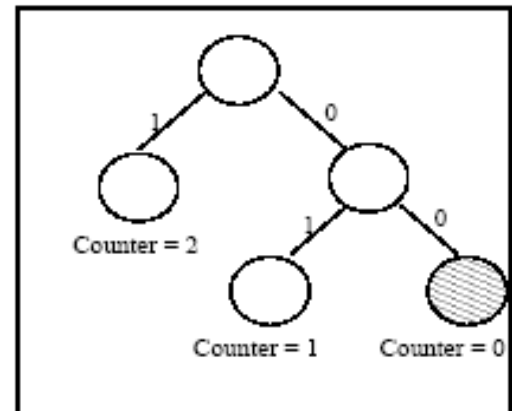
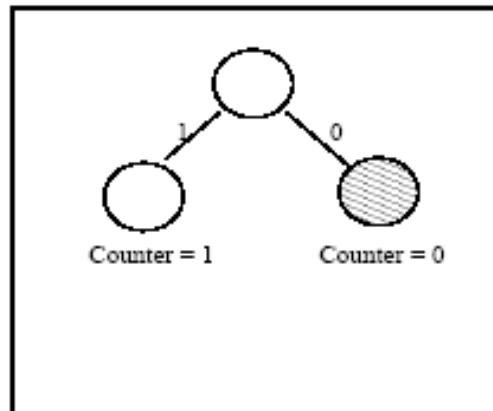
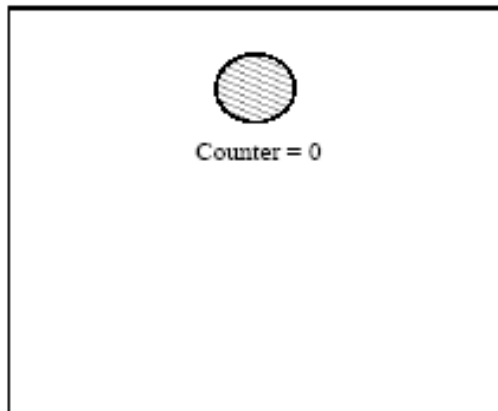
Tree Algorithm

- Reader queries for tags
- Reader informs in case of collision and tags generates 0 or 1 randomly
- If 0 then tag retransmits on next query
- If 1 then tag becomes silent and starts incrementing its counter (which is initially zero)
- Counter incremented every time collision reported and decremented every time identification reported
- Tag remains silent till its counter becomes zero

Tree Algorithm – Example


Reader informs tags in case of collision and tags generate 0 or 1

- If 0 then tag retransmits on next query, else tag becomes silent and starts a counter. Counter incremented every time collision reported and decremented otherwise.



 Unidentified silent tags

 Unidentified tags responding to queries

 Identified silent tags

Tree Algorithm - Complexity

- Time Complexity – $O(n)$ where n is number of tags to be identified
- Message Complexity
 - n is unknown – $\theta(n \log n)$
 - n is known - $\theta(n)$
- Overheads
 - Requires random number generator
 - Requires counter

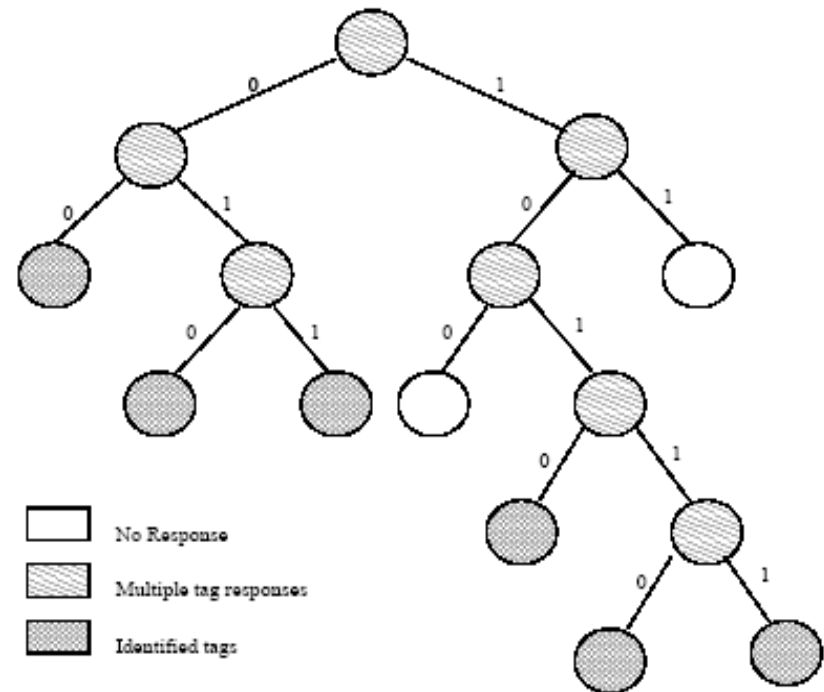
Memoryless Protocol

- Assumption: tagID stored in k bit binary string
- Algorithm
 - Reader queries for prefix p
 - In case of collision queries for p_0 or p_1
- Time complexity
 - Running time – $O(n)$
 - Worst Case – $n^*(k + 2 - \log n)$
- Message Complexity – $k^*(2.21 \log n + 4.19)$

Memoryless Protocol – Example

- Reader queries for prefix p
- In case of collision, reader queries for $p0$ or $p1$
- Example: consider tags with prefixes: 00111, 01010, 01100, 10101, 10110 and 10111

Step	Query Prefix	Response
1	0	Collision
2	1	Collision
3	00	00111 (Identified)
4	01	Collision
5	10	Collision
6	11	No Response
7	010	01010 (Identified)
8	011	01100 (Identified)
9	100	No Response
10	101	Collision
11	1010	10101 (Identified)
12	1011	Collision
13	10110	10110 (Identified)
14	10111	10111 (Identified)

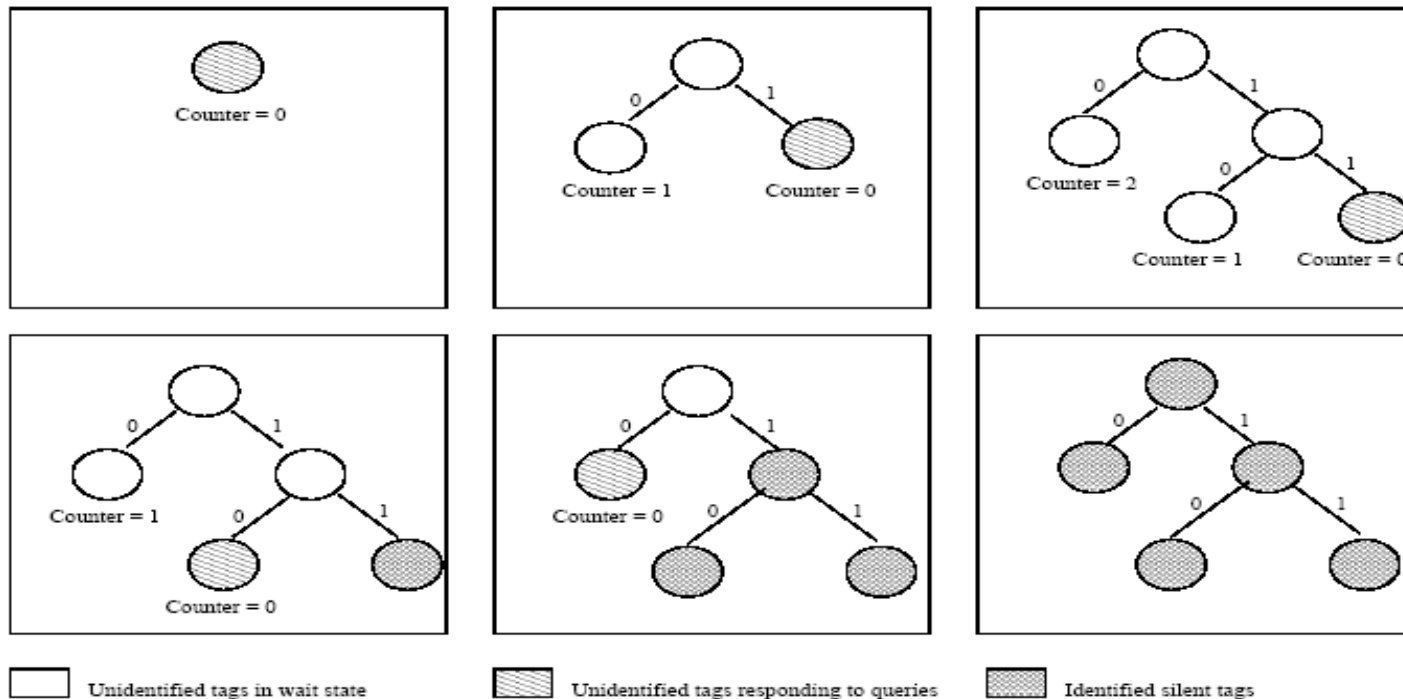


Contactless Protocol

- Assumption: tagID stored in k bit binary string
- Algorithm
 - Reader queries for (i)th bit
 - Reader informs in case of collision
 - Tags with (i)th bit 0 become silent and maintain counter
 - Tags with (i)th bit 1 respond to next query for (i+1)th bit
- Time complexity – $O(2^k)$
- Message complexity – $O(m(k+1))$, where m is number of tags

Contactless Protocol – Example

- Reader queries for (i)th bit
- Reader informs in case of collision
 - Tags with (i)th bit 0 become silent and maintain counter
 - Tags with (i)th bit 1 respond to next query for (i+1)th bit
- Example: tags with prefixes: 01, 10 and 11



I-Code Protocol

- Based on slotted ALOHA principle
- Algorithm
 - Reader provides time frame with N slots, N calculated for estimate n of tags
 - Tags randomly choose a slot and transmit their information
 - Responses possible for each slot are
 - Empty, no tag transmitted in this slot – c_0
 - Single response, identifying the tag – c_1
 - Multiple responses, collision – c_k

I-Code Protocol

- New estimate for n : lower bound

$$\varepsilon_{lb}(N, c_0, c_1, c_k) = c_1 + 2c_k$$

N slots	1	4	8	16	31	64	128	256
n_low	-	-	-	1	10	17	51	112
n_high	-	-	-	9	27	56	129	∞

- Using estimate n , N calculated
- N becomes constant after some time
- Using this N calculate number of read cycles s to identify tags with a given level of accuracy α
- Time complexity – $t_0^*(s+p)$
 - t_0 is time for one read cycle
 - p number of read cycles for estimating N
- Message complexity – $n^*(s+p)$

Outline

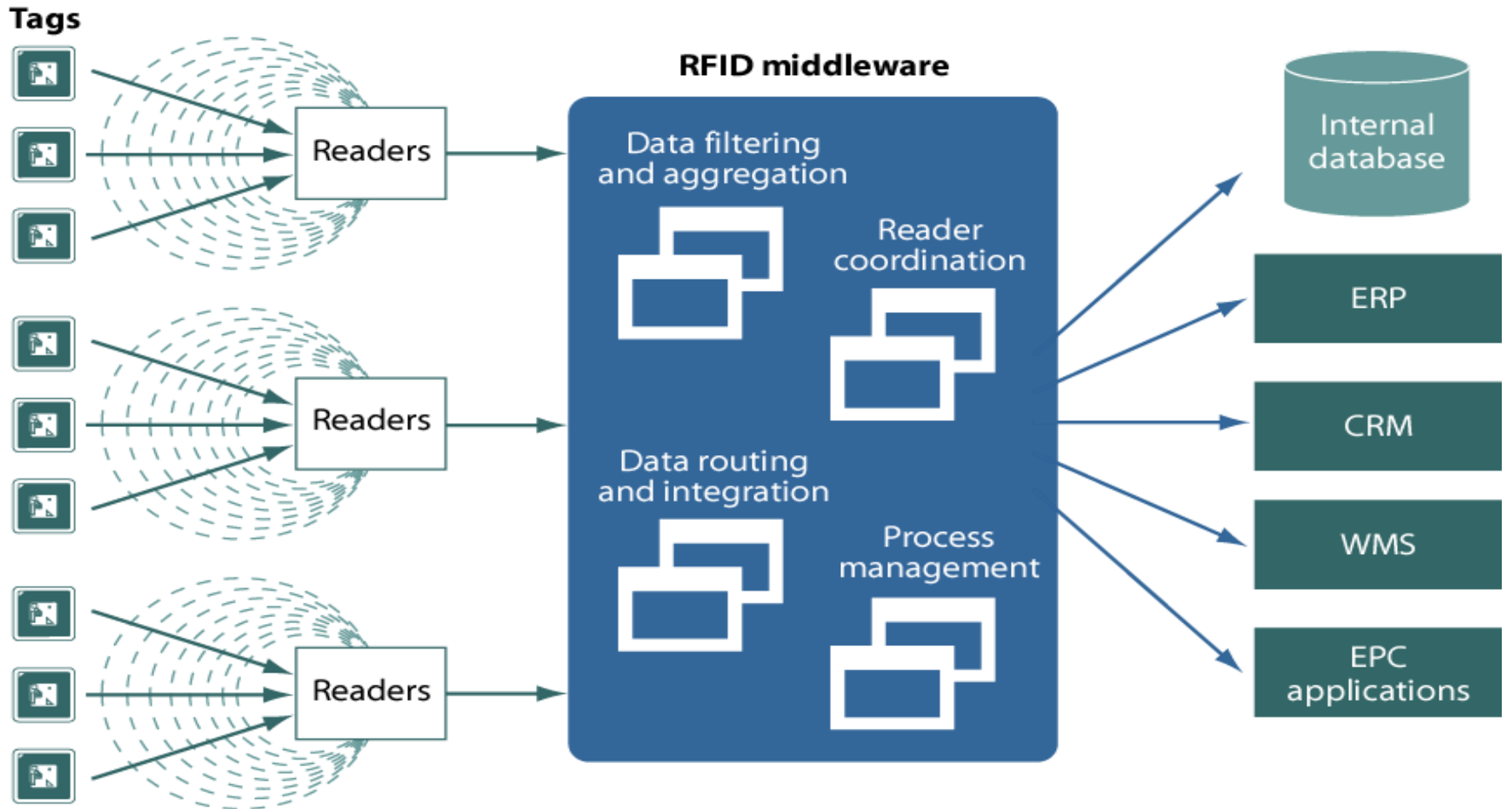
- Overview of RFID
 - Reader-Tag; Potential applications
- RFID Technology Internals
 - RF communications; Reader/Tag protocols
 - **Middleware architecture; EPC standards**
- RFID Business Aspects
- Security and Privacy
- Conclusion

How much data?

Consider a supermarket chain implementing RFID:

- 12 bytes EPC + Reader ID + Time = 18 bytes per tag
- Average number of tags in a neighborhood store = 700,000
- Data generated per second = 12.6 GB
- Data generated per day = 544 TB
- Assuming 50 stores in the chain,
 - data generated per day = 2720 TB
- Stanford Linear Accelerator Center generates 500 TB

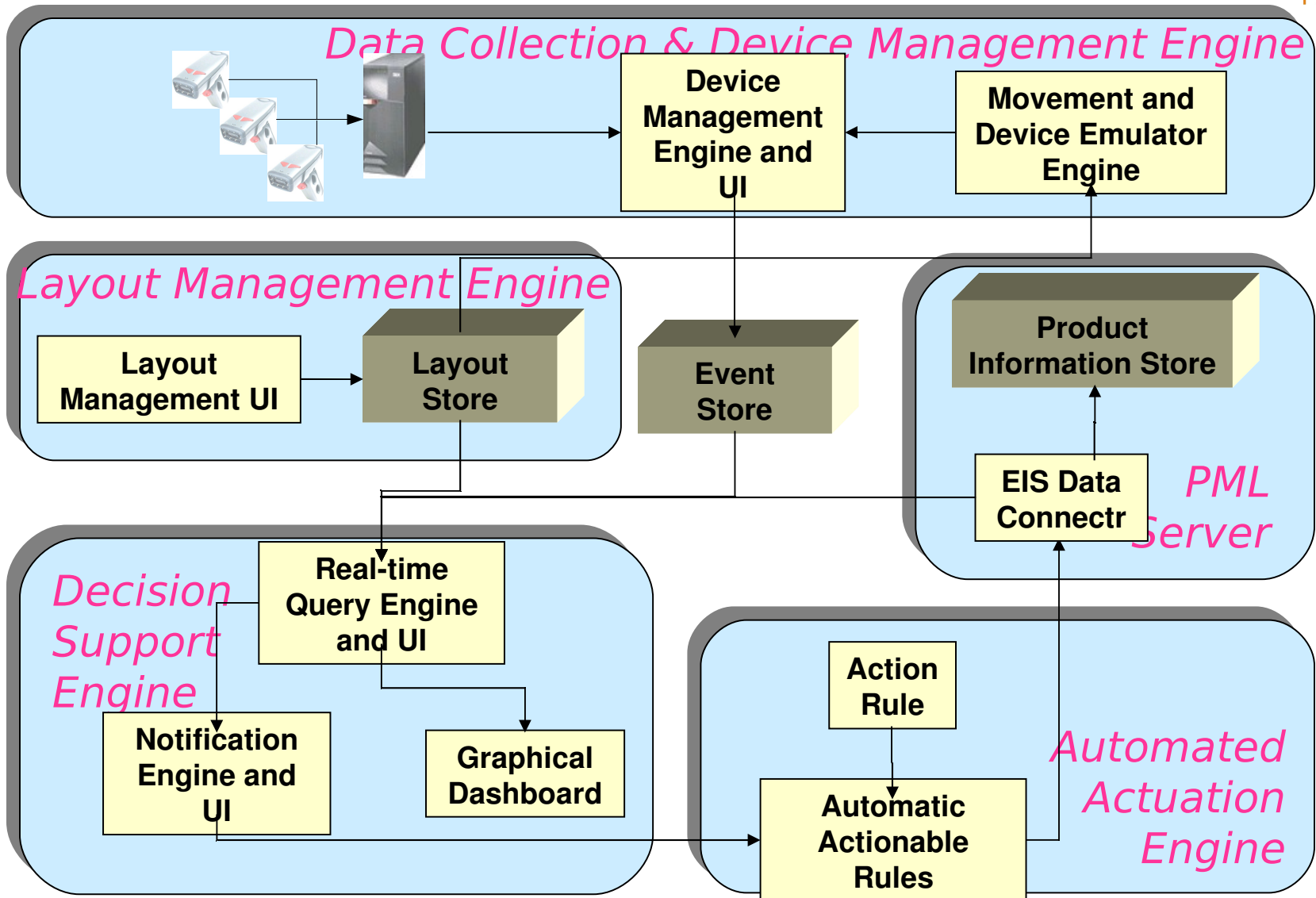
RFID middleware



Middleware framework: PINES™

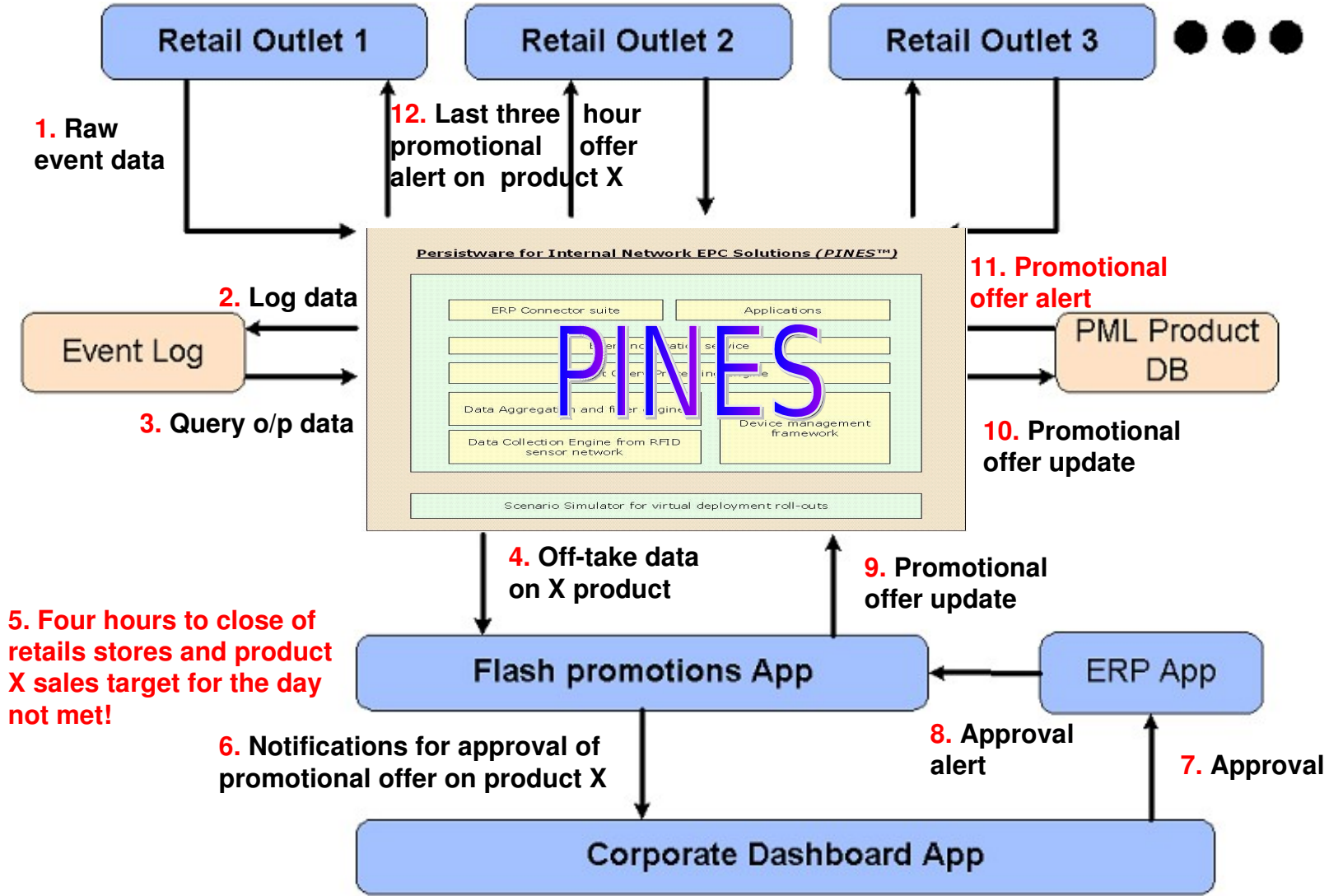


PERSISTENT

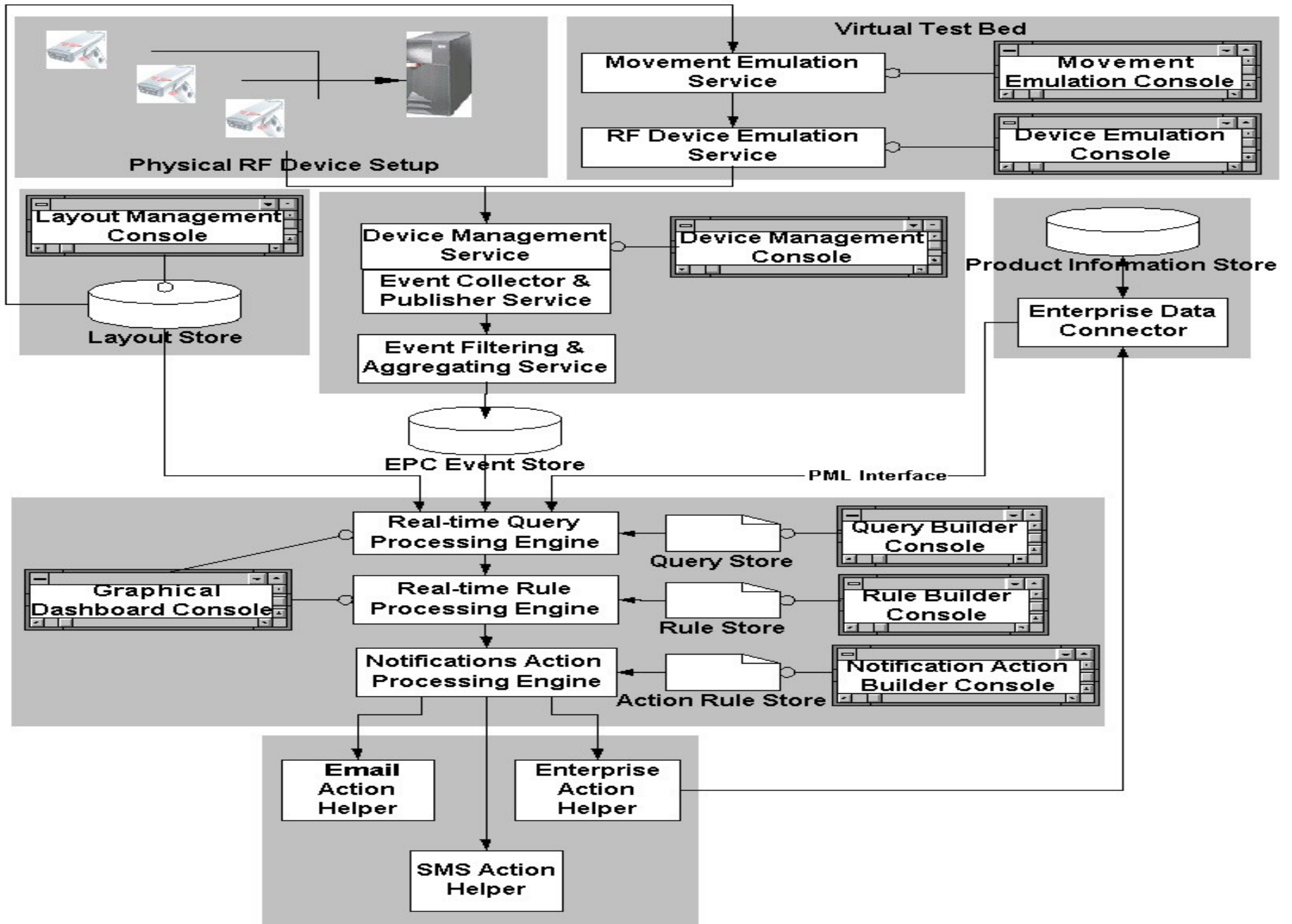




Retail case study: Enabling real-time decisions



PINES™ Architecture Overview

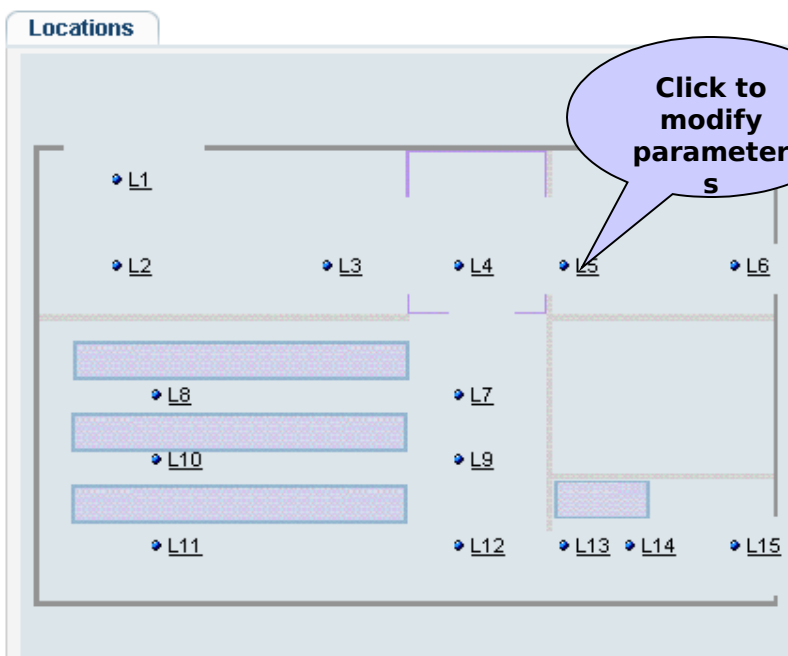


Layout Management Framework

Site Layout Configuration and Location Management

- Administration Console
 - Layout Management
 - Device Management
 - Event Store Management
- Emulation Console
 - Movement Emulation
 - Hardware Emulation

Layout Map



Scale

North (1 Unit = 7px) East (1 Unit = 12px)

	Desc	Point	From
Jn	Entry L1	[20, 6, 0]	main
	L2	[16, 6, 0]	main
Jn	L3	[16, 22, 0]	main
	L4	[16, 32, 0]	main
Jn	L5	[16, 40, 0]	main
Jn	Exit L6	[16, 53, 0]	main
	L7	[10, 32, 0]	main
Jn	L8	[10, 9, 0]	main
	L9	[7, 32, 0]	main
Jn	L10	[7, 9, 0]	main
	L11	[3, 9, 0]	main
Jn	L12	[3, 32, 0]	main
	L13	[3, 40, 0]	main
Jn	Exit L15	[3, 53, 0]	main

- Specify the layout for a reader and antenna setup by means of locations and junctions
- Ability to continuously modify/update the layout
- Provide access to reader and antenna configuration from visual layout

Jn Location "represents Business Processing Zone" or "Positions RF Antenna"

Entry Location that accepts goods within system boundaries

Exit Location that dispatches goods to outside of

Microsoft Internet Explorer browser window showing the PINES™ application interface. The address bar displays `http://localhost:8080/pines/index.jsp`. The interface includes a navigation menu with 'Home', 'Applications', and 'Configuration' tabs. A sidebar on the left contains sections for 'Administration Console', 'Emulation Console', and 'Service Console'. The main content area is titled 'Layout Definition' and features a 'Site Properties' table and a 'Floor Properties' table. Two callout boxes highlight the 'Site Definition' and the relationship 'One site = Many floors'.

Site Properties	
Site Name	Site 1
Breadth	300 mtrs
Length	200 mtrs
Origin	(0,0)
Floor	1

Floor Properties	
Floor Level	1
Floor Height	5.0
Description	Floor 1

PINES - Microsoft Internet Explorer provided by PA-SP-CP Site
 File Edit View Favorites Tools Help
 Address http://localhost:8080/pines/index.jsp
 Links Design Patterns Tutorial Extreme Programming A Gentle Introduction. Google HowStuffWorks - Learn how Everything Works! index Introduction to SSL

PINES™
 Home Applications Configuration

Administration Console
 Layout Management
 Device Management

Emulation Console
 Goods Movement Emulation

Service Console
 LoggerService
 NotificationService
 QueryFilterService

Floor Properties
 Site Site
 Floor Level 1

Zone Properties
 Zone Zone 1
 Breadth 120.0
 Length 200.0
 Reference Pt (20 , 10)

SITE: Site FLOOR: 1
 0 0 30 60 90 120 150 180 210 240 270 300
 0
 20
 40
 60
 80
 100
 120
 140
 160
 180
 200

Zone 1

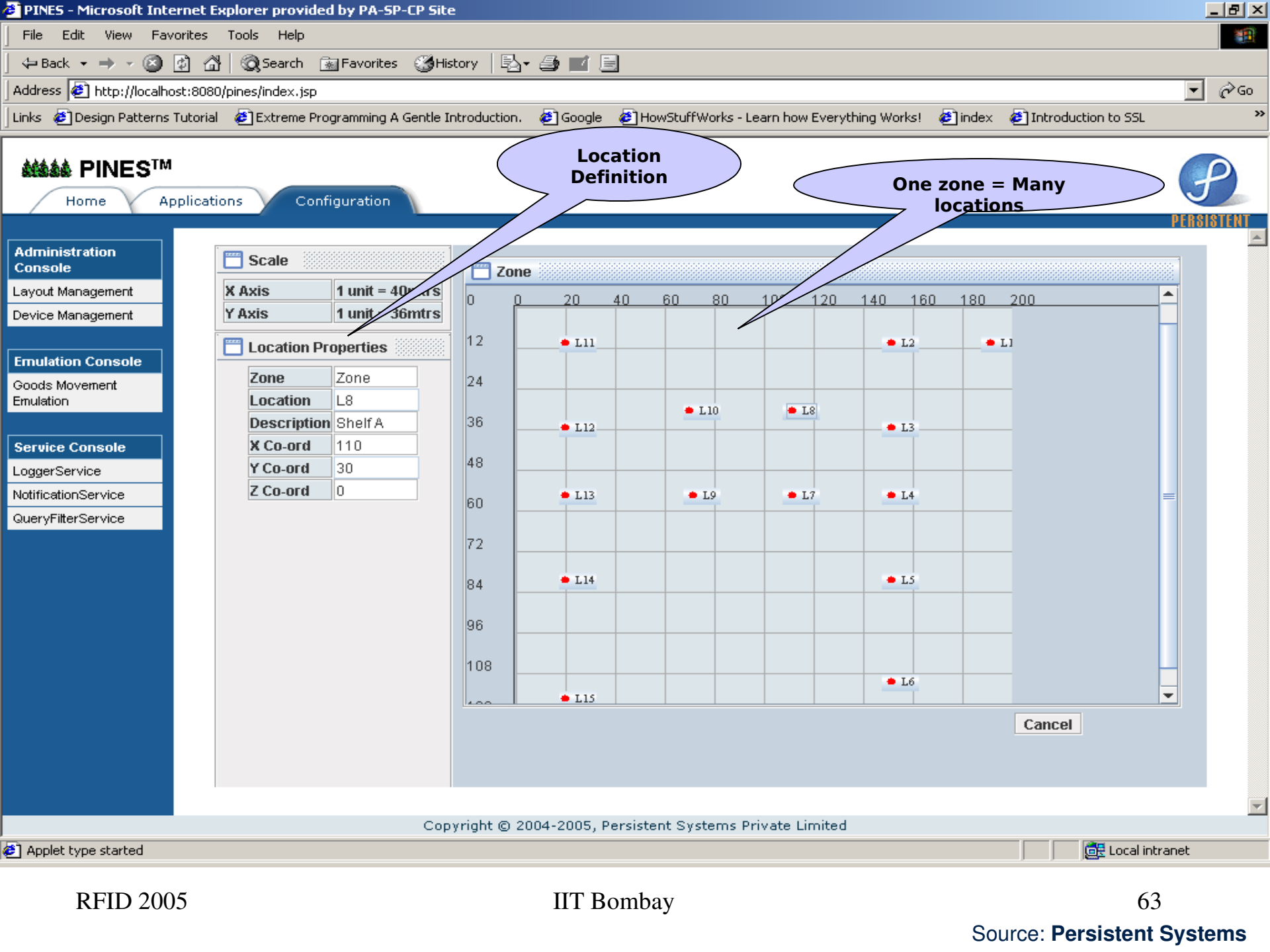
Back Browse Zone Cancel

Copyright © 2004-2005, Persistent Systems Private Limited
 Applet in.co.persistent.pines.gui.layoutmanagement.ZoneDesign started Local intranet

Floor Definition

Zone Definition

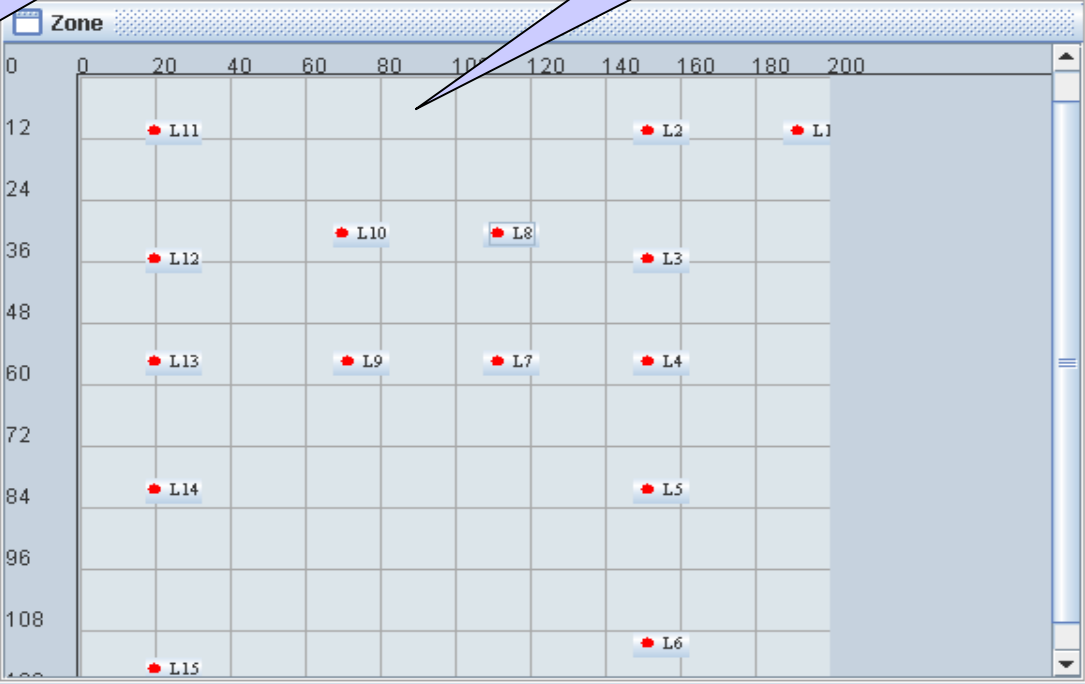
One site = Many zones



- Administration Console**
 - Layout Management
 - Device Management
- Emulation Console**
 - Goods Movement Emulation
- Service Console**
 - LoggerService
 - NotificationService
 - QueryFilterService

Scale	
X Axis	1 unit = 40mtrs
Y Axis	1 unit = 36mtrs

Location Properties	
Zone	Zone
Location	L8
Description	Shelf A
X Co-ord	110
Y Co-ord	30
Z Co-ord	0

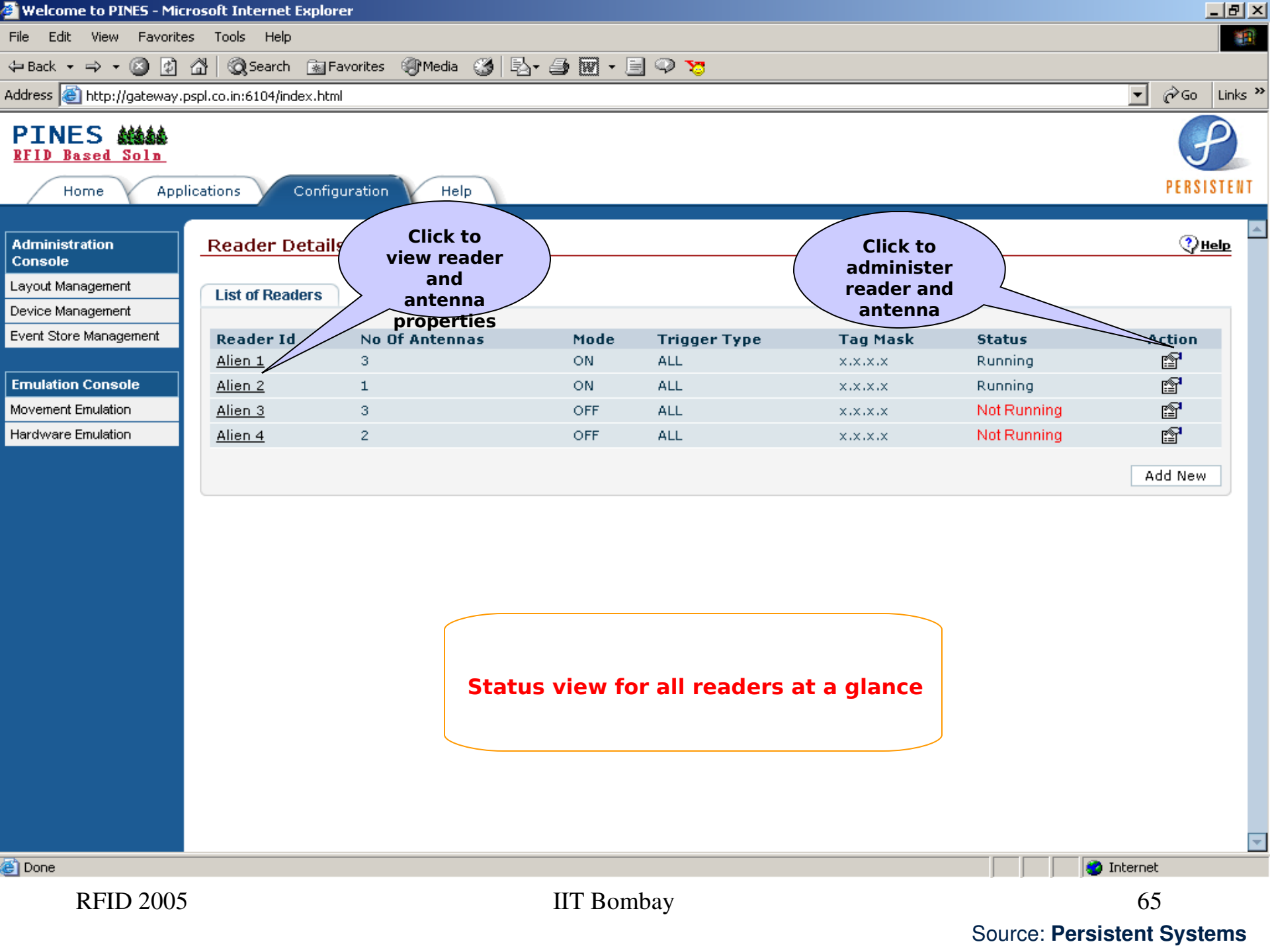


Location Definition

One zone = Many locations

Device Management Framework

**Remote monitoring and configuration
of RF Sensor network elements -
Readers and Antennas**



Reader Details

List of Readers

Reader Id	No Of Antennas	Mode	Trigger Type	Tag Mask	Status	Action
Alien 1	3	ON	ALL	x.x.x.x	Running	
Alien 2	1	ON	ALL	x.x.x.x	Running	
Alien 3	3	OFF	ALL	x.x.x.x	Not Running	
Alien 4	2	OFF	ALL	x.x.x.x	Not Running	

Add New

Click to view reader and antenna properties

Click to administer reader and antenna

Status view for all readers at a glance

Reader Details Reader definition

Reader Settings

Reader Id	Alien 1
No Of Antennas	3
Reader Mode	ON
IP Address	192.168.2.2
Port	3300
Notify Trigger	ALL
Tag Mask	x.x.x.x
Status	Running

Physical Attributes

Communication Mode	Serial
Reader Type	Nanoscanner
Operating Frequency	915
Power	10
Location	Not Set

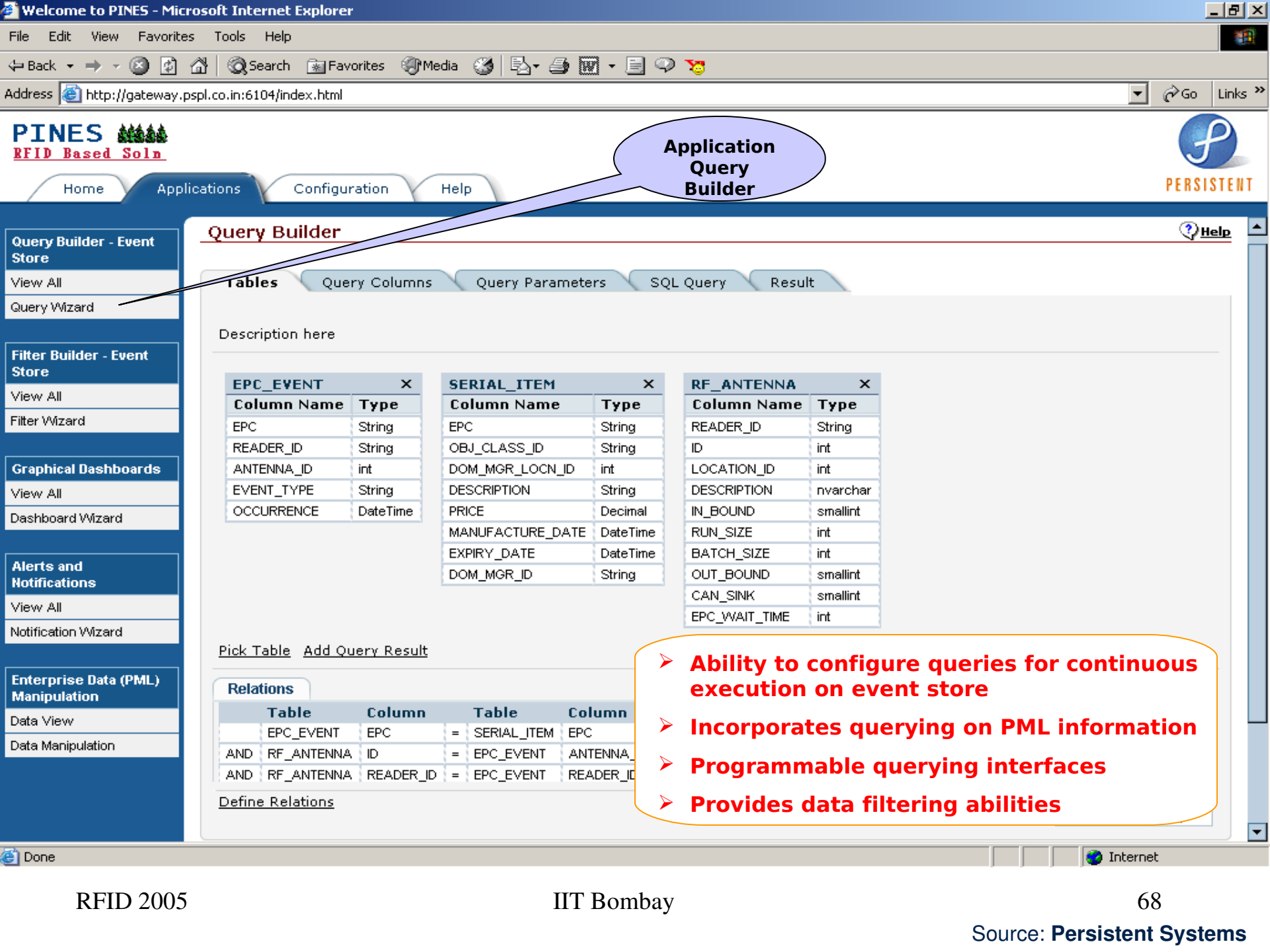
Antenna List

Id	Name	Location	Operational
2	Name 3	Not Set	Yes
1	Name 2	Not Set	Yes
0	Name 1	Not Set	Yes

- Reader and Antenna configuration and status view for specific reader
- Ability to remotely monitor and configure Reader and Antenna parameters

Sophisticated Query Processing

**Stream based event store for incessant,
high performance querying**



Application Query Builder

Query Builder - Event Store

View All

Query Wizard

Filter Builder - Event Store

View All

Filter Wizard

Graphical Dashboards

View All

Dashboard Wizard

Alerts and Notifications

View All

Notification Wizard

Enterprise Data (PML) Manipulation

Data View

Data Manipulation

Query Builder

Tables

Query Columns

Query Parameters

SQL Query

Result

Description here

Column Name	Type
EPC	String
READER_ID	String
ANTENNA_ID	int
EVENT_TYPE	String
OCCURRENCE	DateTime

Column Name	Type
EPC	String
OBJ_CLASS_ID	String
DOM_MGR_LOCN_ID	int
DESCRIPTION	String
PRICE	Decimal
MANUFACTURE_DATE	DateTime
EXPIRY_DATE	DateTime
DOM_MGR_ID	String

Column Name	Type
READER_ID	String
ID	int
LOCATION_ID	int
DESCRIPTION	nvarchar
IN_BOUND	smallint
RUN_SIZE	int
BATCH_SIZE	int
OUT_BOUND	smallint
CAN_SINK	smallint
EPC_WAIT_TIME	int

Pick Table Add Query Result

Relations

	Table	Column		Table	Column
	EPC_EVENT	EPC	=	SERIAL_ITEM	EPC
AND	RF_ANTENNA	ID	=	EPC_EVENT	ANTENNA_ID
AND	RF_ANTENNA	READER_ID	=	EPC_EVENT	READER_ID

Define Relations

- Ability to configure queries for continuous execution on event store
- Incorporates querying on PML information
- Programmable querying interfaces
- Provides data filtering abilities

Snapshot of all Queries

Query Builder - Event Store

View All

Query Wizard

Filter Builder - Event Store

View All

Filter Wizard

Graphical Dashboards

View All

Dashboard Wizard

Alerts and Notifications

View All






















Notification Wizard

Enterprise Data (PML) Manipulation

Data View

Data Manipulation

Query List ? Help

Select	Title	Administration	View
<input type="checkbox"/>	<u>Event Log</u> This Window Shows the complete log	SQL  	SQL
<input type="checkbox"/>	<u>Stock Report - Product wise</u> Show the product wise stock at the warehouse.	SQL  	SQL 
<input type="checkbox"/>	<u>Stock Report - Location wise</u> Show the Productwise - Locationwise stock at the warehouse.	SQL  	SQL 
<input type="checkbox"/>	<u>Non-Moving Stock</u> List all the products which are at the warehouse more than 15 minutes.	SQL  	SQL
<input type="checkbox"/>	<u>Warranty Expiry Tracking</u> List all the products with their remaining days for Expiry.	SQL  	SQL
<input type="checkbox"/>	<u>Warranty Expired Products</u> Show all the expired products in the warehouse.	SQL  	SQL
<input type="checkbox"/>	<u>Process Tracking</u> Show the average time taken by each Processing Unit to process a product.	SQL  	SQL
<input type="checkbox"/>	<u>Stock Received - 30 MINS</u> Show how much stock is arrived in last half Hr for each product.	SQL  	SQL
<input type="checkbox"/>	<u>All Product Types</u> Show all product types.	SQL  	SQL 

Delete Add New

- Access configuration panels of specific queries
- View tabular and graphical outputs for all queries

Dashboards

Corporate dashboards for enhanced decision making

PINES - Microsoft Internet Explorer provided by PA-SP-CP Site
 File Edit View Favorites Tools Help
 Back Forward Stop Home Search Favorites History Print Copy Paste
 Address http://localhost:8080/pines/index.jsp Go
 Links Design Patterns Tutorial Extreme Programming A Gentle Introduction. Google HowStuffWorks - Learn How Everything Works! index Introduction to SSL

Results - Microsoft Internet Explorer provided by PA-SP-CP Site
Show the log of events of tags detected. Refresh

Total Number Of Records = 30

PROD_ITEM_EPC	LOCATION_ID	MOVEMENT	OCCURRENCE
54.11.12.363	L1	IN	Sep 7 2004 4:51PM
54.11.12.520	L1	IN	Sep 7 2004 4:51PM
54.11.12.622	L1	IN	Sep 7 2004 4:51PM
54.11.12.640	L1	IN	Sep 7 2004 4:51PM
54.11.38.3287	L1	IN	Sep 7 2004 4:51PM
54.11.38.436	L1	IN	Sep 7 2004 4:51PM
54.11.38.9670	L1	IN	Sep 7 2004 4:51PM
54.22.15.4901	L1	IN	Sep 7 2004 4:51PM
54.22.15.8337	L1	IN	Sep 7 2004 4:51PM
54.22.16.1	L1	IN	Sep 7 2004 4:51PM
54.22.16.1215	L1	IN	Sep 7 2004 4:51PM
54.22.16.22	L1	IN	Sep 7 2004 4:51PM
54.22.22.488	L1	IN	Sep 7 2004 4:51PM
54.33.11.181	L1	IN	Sep 7 2004 4:51PM
54.33.11.2345	L1	IN	Sep 7 2004 4:51PM
54.33.11.6596	L1	IN	Sep 7 2004 4:51PM
54.33.22.1779	L1	IN	Sep 7 2004 4:51PM
54.33.22.1846	L1	IN	Sep 7 2004 4:51PM
54.33.22.4594	L1	IN	Sep 7 2004 4:51PM
54.33.22.5190	L1	IN	Sep 7 2004 4:51PM
54.11.12.4235	L1	IN	Sep 7 2004 4:49PM

Done Local intranet

Copyright © 2004-2005, Persistent Systems Private Limited

javascript:viewResult('event_log_query','Show the log of events of tags detected.','10000') Local intranet

Query definition

Query result snapshot

File Edit View Favorites Tools Help

Address http://localhost:8080/pines/index.jsp

Links Design Patterns Tutorial Extreme Programming A Gentle Introduction. Google HowStuffWorks - Learn how Programming Works! index Introduction to SSL

PINES™

Home Applications

Result Dashboards
View All

Event Notification Map
View All

List Of

Title

- Event Log
- Product Wa
- Stock of Ite
- Stock Rece
- Current Pall
- Stock of Ite
- Spuriously
- Stock Repo
- Stock Non M
- Stock Repo
- Today's Pall

Results - Microsoft Internet Explorer provided by PA-SP-CP Site

Show the current pallet/case/item stock count at the arrival dock. ?

Total Number Of Records = 1 Refresh

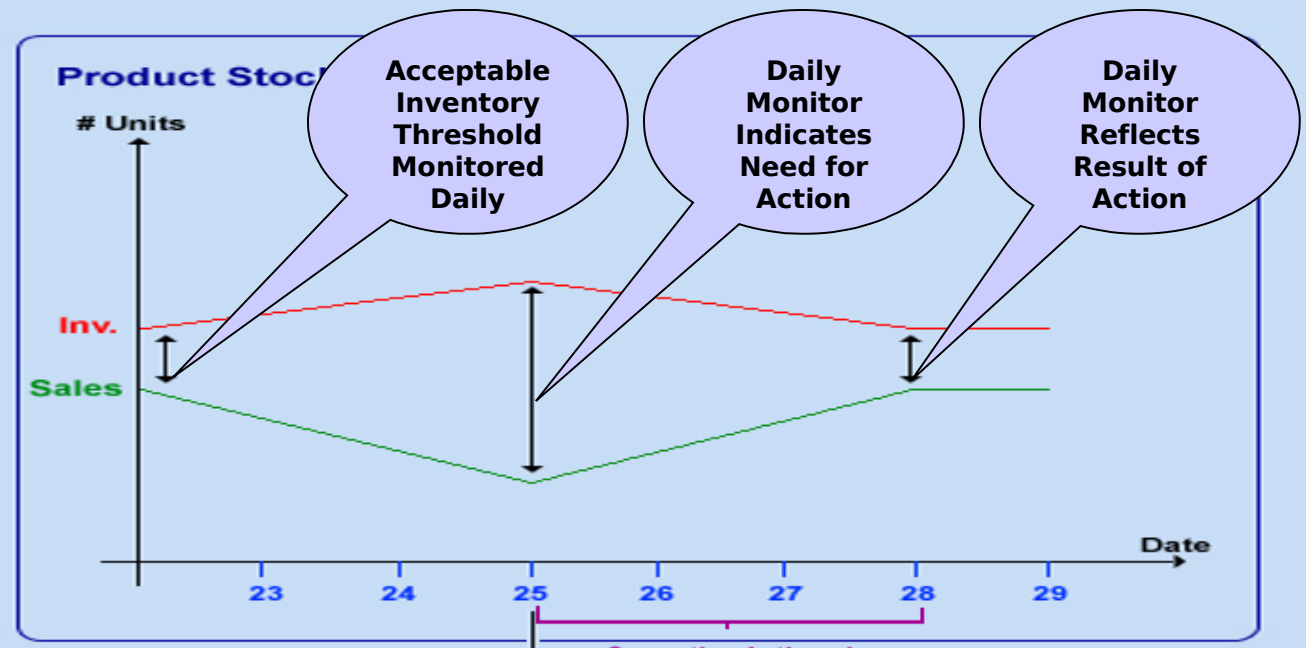
COUNT
108

Done Done Local intranet

Query definition

Query result snapshot

- Query Builder - Event Store
View All
Query Wizard
- Filter Builder - Event Store
View All
Filter Wizard
- Graphical Dashboards
View All
Dashboard Wizard
- Alerts and Notifications
View All
Notification Wizard
- Enterprise Data (PML) Manipulation
Data View
Data Manipulation



Notification on sales target not being met



➤ **Flash promotions application as reflected in a corporate dashboard**

Welcome to PINES - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://gateway.pspl.co.in:6104/index.html

PINES RFID Based Soln

Home Applications Configuration Help

Graph Wizard

Main Graph Sub Graph

Graph Title

Selected query: Event Log

Color Scheme: blues

Auto Refresh interval (in seconds)

Graph Type

- Bar
- Line
- Area
- Pie

Bar Graph

	Column	Title
x-axis	product type	Product Type
y-axis	product quantity	Stock

Legend

For Column: Stock

Color	Condition	Value
	<=	5
	<=	15
	>	15

Save Cancel

Graphical dashboard builder to provide visual view over query

- Choose from multiple types of graphs
- Configuration panels for visualization effects
- Configuration panels for drilled down views

Done

Start | Inbox - M... | Adobe Ph... | RFIDmay... | PINES - K... | NewPINE... | Welcom... | Untitled - ... | Internet | 4:45 PM

Welcome to PINES - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://gateway.pspl.co.in:6104/index.html

PINES RFID Based Soln

Home Applications Configuration Help

PERSISTENT

Graph View of Prebuilt Queries

LocationWise Details about a Specific Product (DiscMan)

Location	Quantity
L1	18
L2	3
L4	9
L7	3
L8	4
L12	2
L14	2

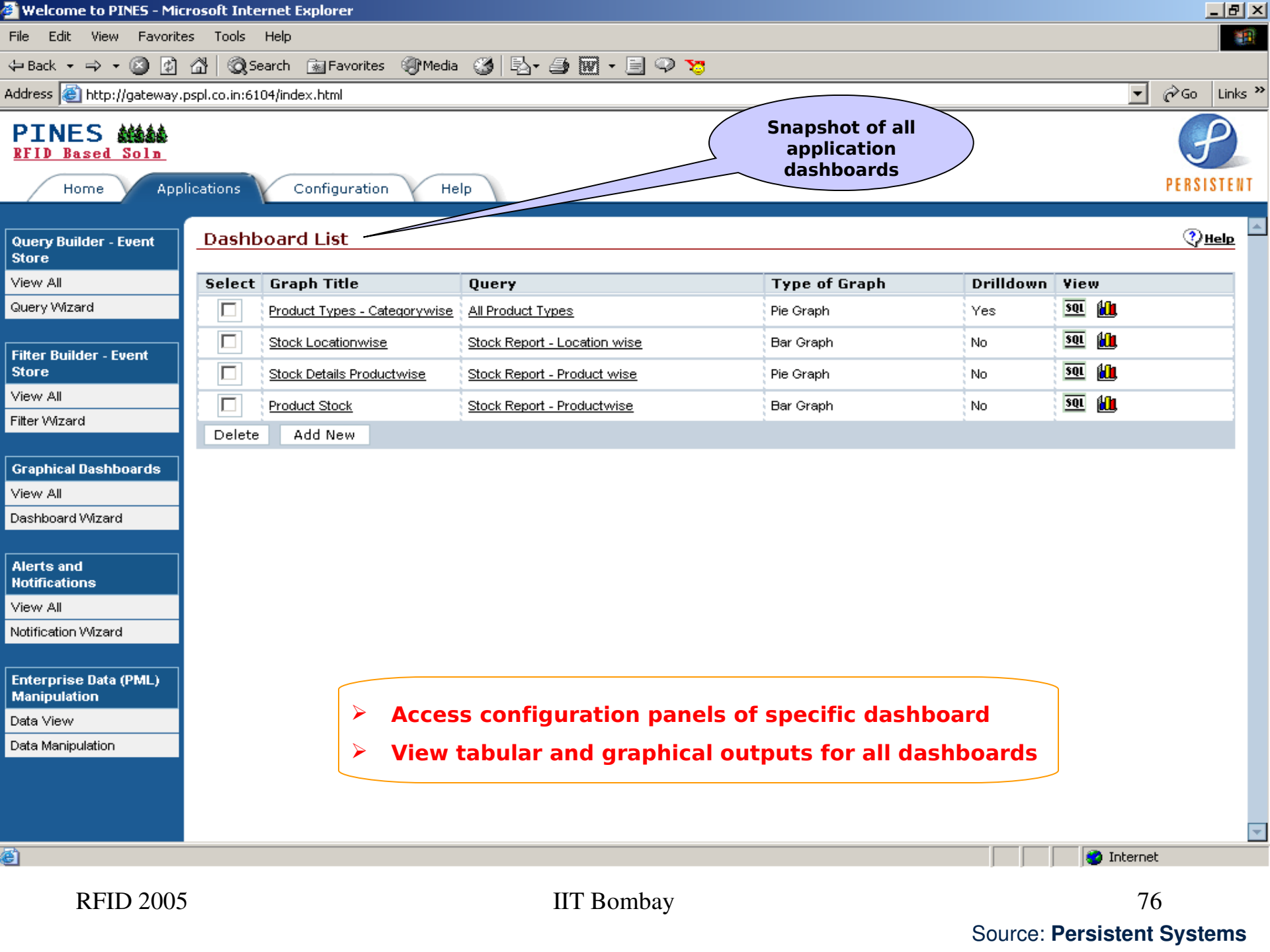
Legend

- X Axis - Location In Warehouse
- Y Axis - Quantity in Numbers

Color Schemes

- Blues
- Pastel Colors
- Buisness
- Formal
- Default
- Monotone
- GrayScale
- Nature

Drill-down view of Query result



Snapshot of all application dashboards

Dashboard List

Select	Graph Title	Query	Type of Graph	Drilldown	View
<input type="checkbox"/>	Product Types - Categorywise	All Product Types	Pie Graph	Yes	SQL
<input type="checkbox"/>	Stock Locationwise	Stock Report - Location wise	Bar Graph	No	SQL
<input type="checkbox"/>	Stock Details Productwise	Stock Report - Product wise	Pie Graph	No	SQL
<input type="checkbox"/>	Product Stock	Stock Report - Productwise	Bar Graph	No	SQL

Delete Add New

- Access configuration panels of specific dashboard
- View tabular and graphical outputs for all dashboards

Notifications

Notifications for enhanced decision making

Configuration panel for notification

Notification Rule Specification [Help](#)

Notification Details

Query For Notification: Stock Report - Product wise

Name of Notification:

Notification Message:

Conditions For Notification

Specify the conditions on which notification is to be given

	Column Name		Criteria	Action
	--Select--		--Select--	Add New
AND	--Select--		--Select--	Remove
AND	--Select--		--Select--	Remove

Notification Action

Specify the action to be taken when Notification condition is satisfied.

Type of Notification: --Select--

List of Recipients (Give a comma separated list of recipients):

Recurrence Required: Define Recurrence Frequency

➤ Specify alerts via email and SMS

Save Cancel

Notifications on Desktop

The screenshot shows a web browser window displaying the PINES™ application. The browser's address bar shows `http://localhost:8080/pines/index.jsp`. The application interface includes a navigation menu with 'Home', 'Applications', and 'Configuration'. A sidebar on the left contains 'Result Dashboards' and 'Event Notification Map'. The main content area is titled 'evt001' and contains an 'Event Subscribers' table with one entry: 'user1' with a description 'Subscriber desc'. A 'Subscriber Details (user 1)' dialog box is open, showing a table with columns 'Email', 'SMS', and 'IM'. The 'Email' column has two rows: 'Preferred Email' with 'email1' and 'Account' with 'swap@persistent.co.in', and 'email2' with an empty account field. Below the table are 'Save' and 'Cancel' buttons. An 'Arrival dock stock overloading' message window is overlaid on the application, showing a message from 'PINES_Notification_Service@persistent.co.in' dated 'Tuesday, September 07, 2004 4:59 PM' to 'swap@persistent.co.in'. The message content includes: 'ID: evt001', 'Priority: 5', 'time: Tue Sep 07 16:59:55 GMT+05:30 2004', 'Action to take: Send more forklifts for fast transfer of stock cases.', 'Timeout: 0', and 'Stock at arrival dock is beyond handling limit. Possibility of overload.' Two callout boxes with lightning bolt tails point to the 'Subscriber Details' dialog and the message window, labeled 'Notification Event Subscriber' and 'Notification Message instance' respectively. The footer of the browser window shows 'Copyright © 2004-2005, Persistent Systems Private Limited' and 'Local intranet'.

Notification Event Subscriber

Notification Message instance

Subscriber Id	Description
<input type="checkbox"/> user1	Subscriber desc

Preferred	Email	Account
<input checked="" type="radio"/>	email1	swap@persistent.co.in
<input type="radio"/>	email2	

Arrival dock stock overloading

From: PINES_Notification_Service@persistent.co.in
Date: Tuesday, September 07, 2004 4:59 PM
To: swap@persistent.co.in
Subject: Arrival dock stock overloading

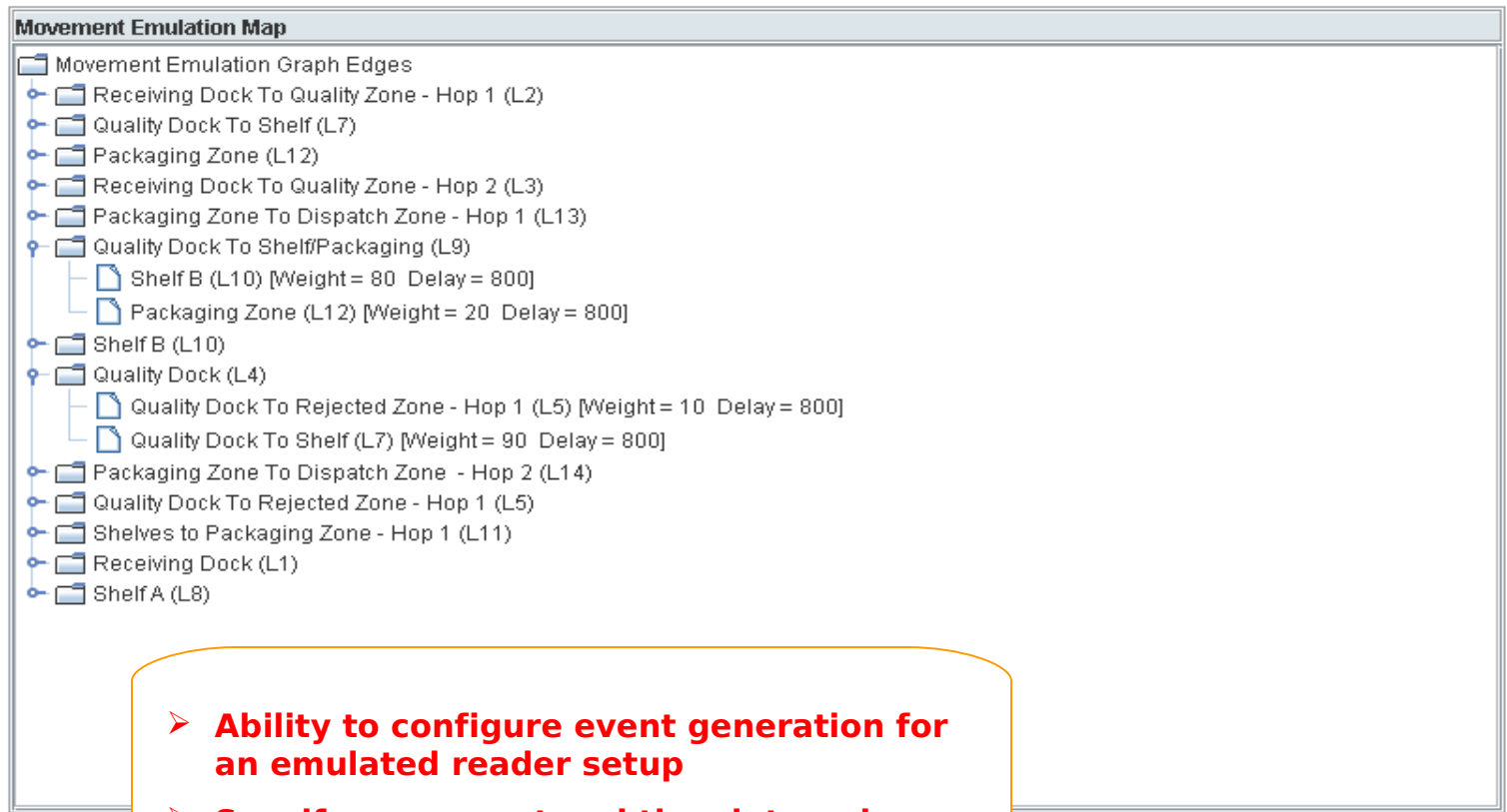
ID: evt001
Priority: 5
time: Tue Sep 07 16:59:55 GMT+05:30 2004
Action to take: Send more forklifts for fast transfer of stock cases.
Timeout: 0

Stock at arrival dock is beyond handling limit. Possibility of overload.

Virtual Test Bed

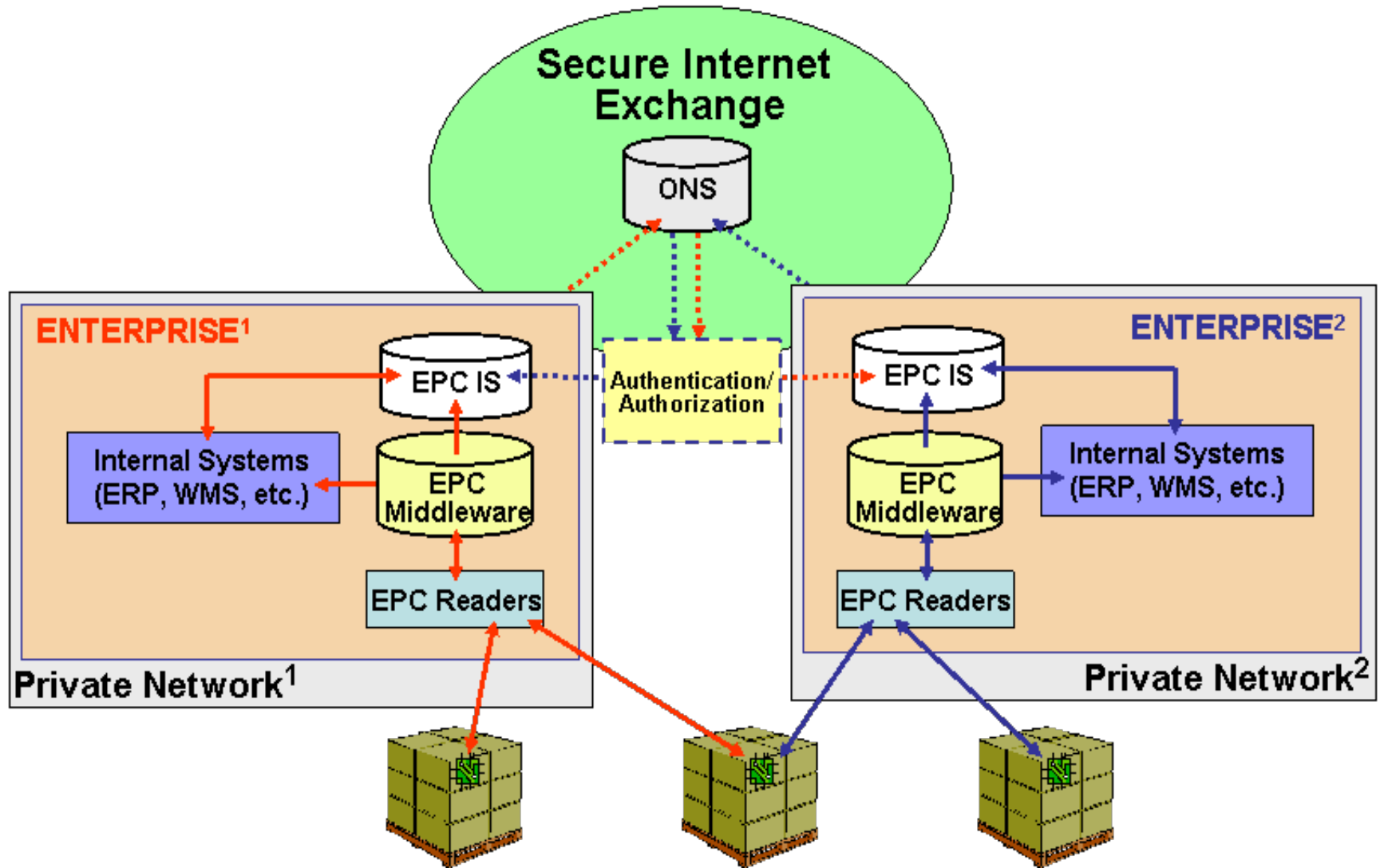
Scenario emulation prior to deployment

- Administration Console**
 - Layout Management
 - Device Management
- Emulation Console**
 - Goods Movement Emulation
- Service Console**
 - LoggerService
 - NotificationService
 - QueryFilterService



- **Ability to configure event generation for an emulated reader setup**
- **Specify movement and time intervals across various functional units**

The EPC model: Internet of Things



EPC and PML

- EPC – Electronic Product Code
 - Header – handles version and upgrades
 - EPC Manager – Product Manufacturer Code
 - Object Class – Class/Type of Product
 - Serial Number – Unique Object Identity
- PML – Physical Markup Language
 - Extension of XML
 - Representation of Tagged Object Information
 - Interaction of Tagged Object Information



Savant and ONS

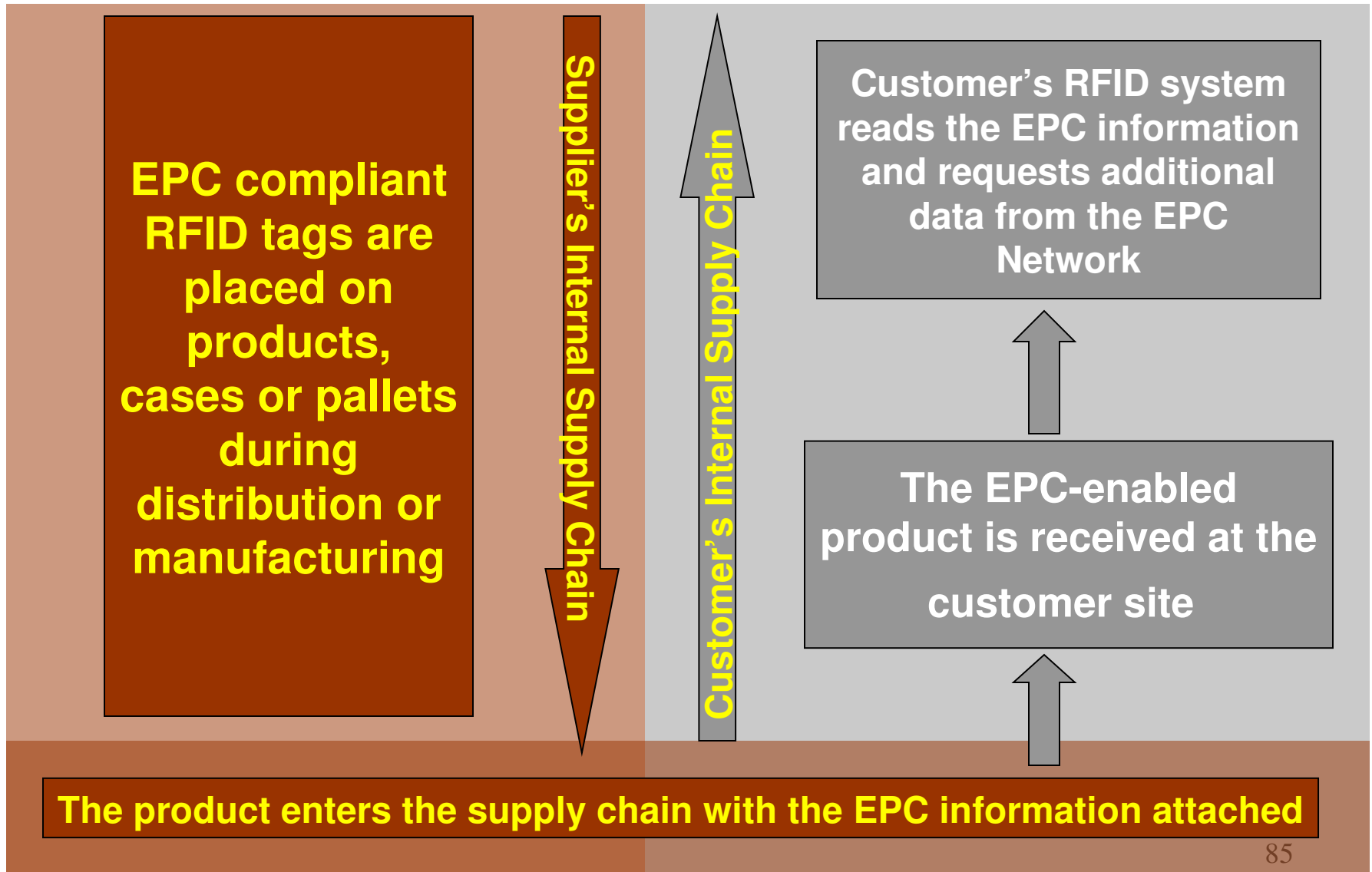
■ Savants

- Manage the flow of EPC data from RFID readers
 - Data smoothing
 - Reader coordination
 - Data forwarding
 - Data storage
- Interact with the ONS network

■ ONS Servers

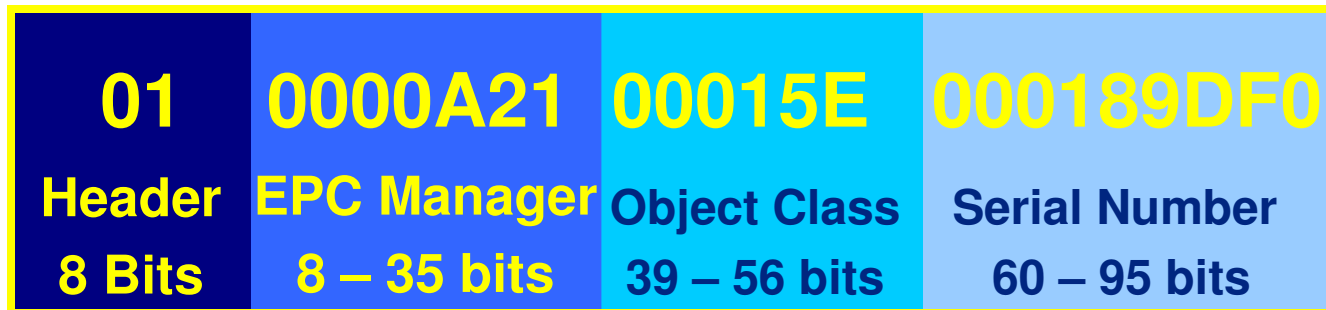
- Directory for EPC information, similar to Internet DNS
- Uses the object manager number of the EPC to find out how to get more information about the product

EPC process flow



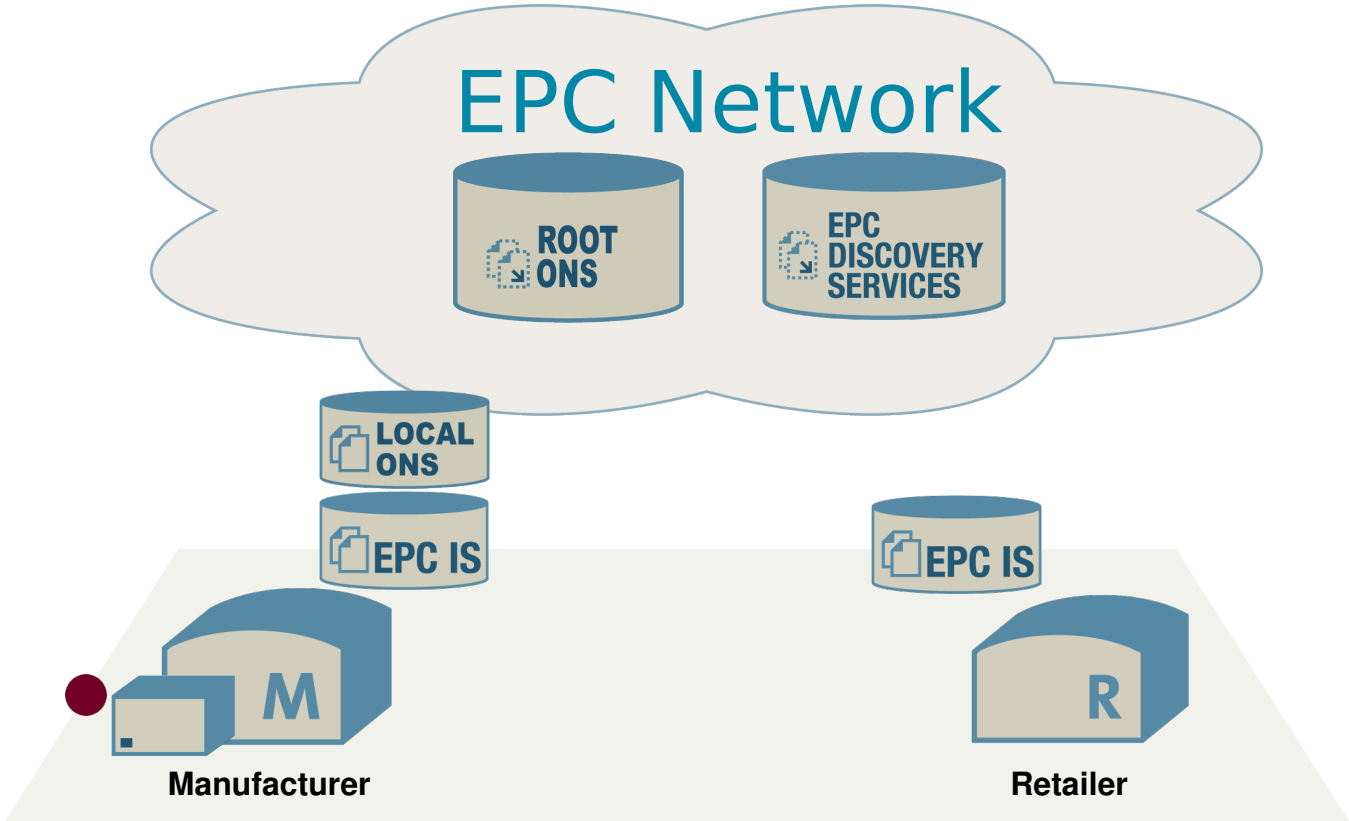
EPC Tags

64 and 96 bit EPC tags have been defined



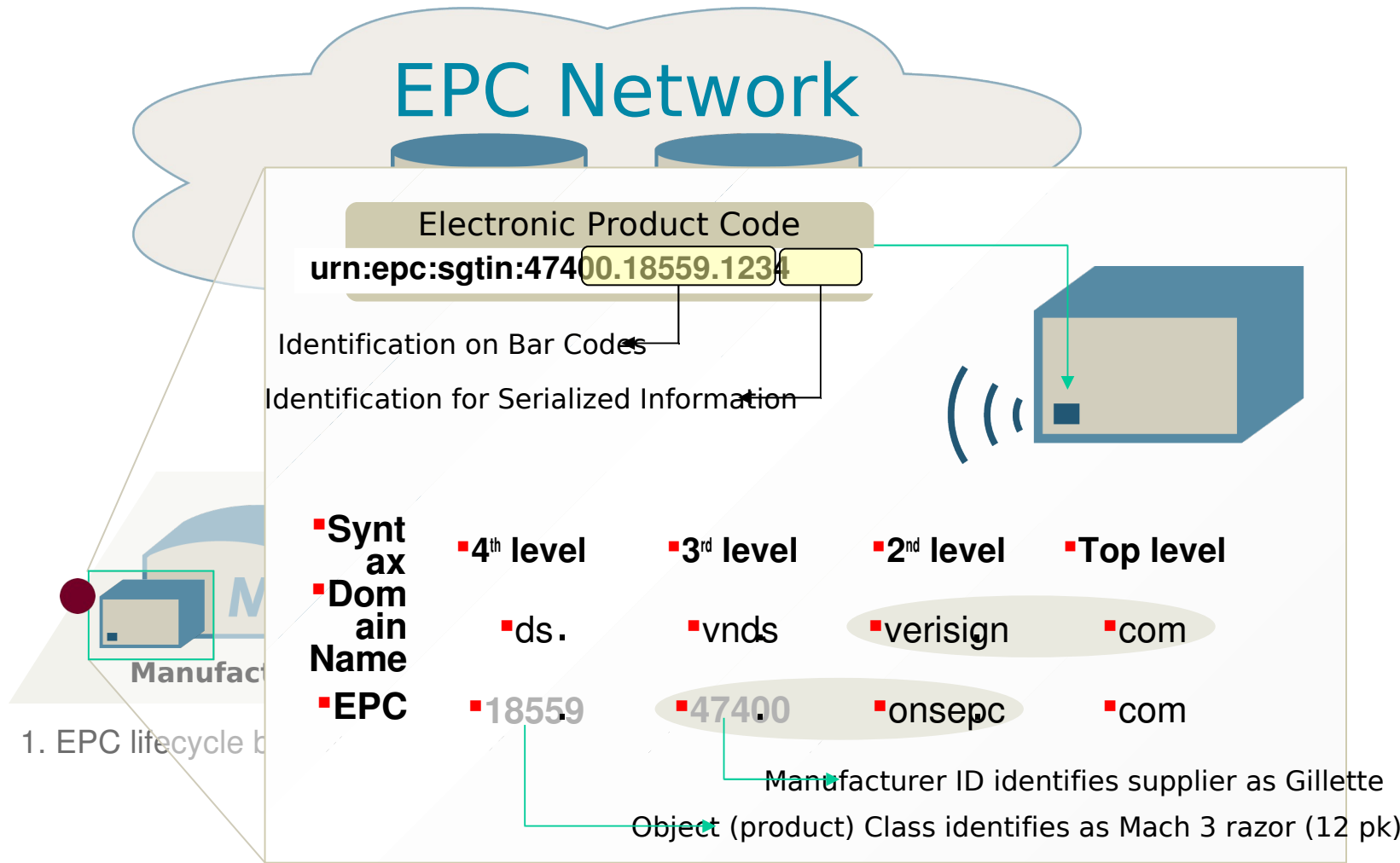
- Allows for unique IDs for 268 million companies
- Each company can then have 16 million object classes
- Each object or SKU can have 68 billion serial numbers assigned to it

The EPC Network

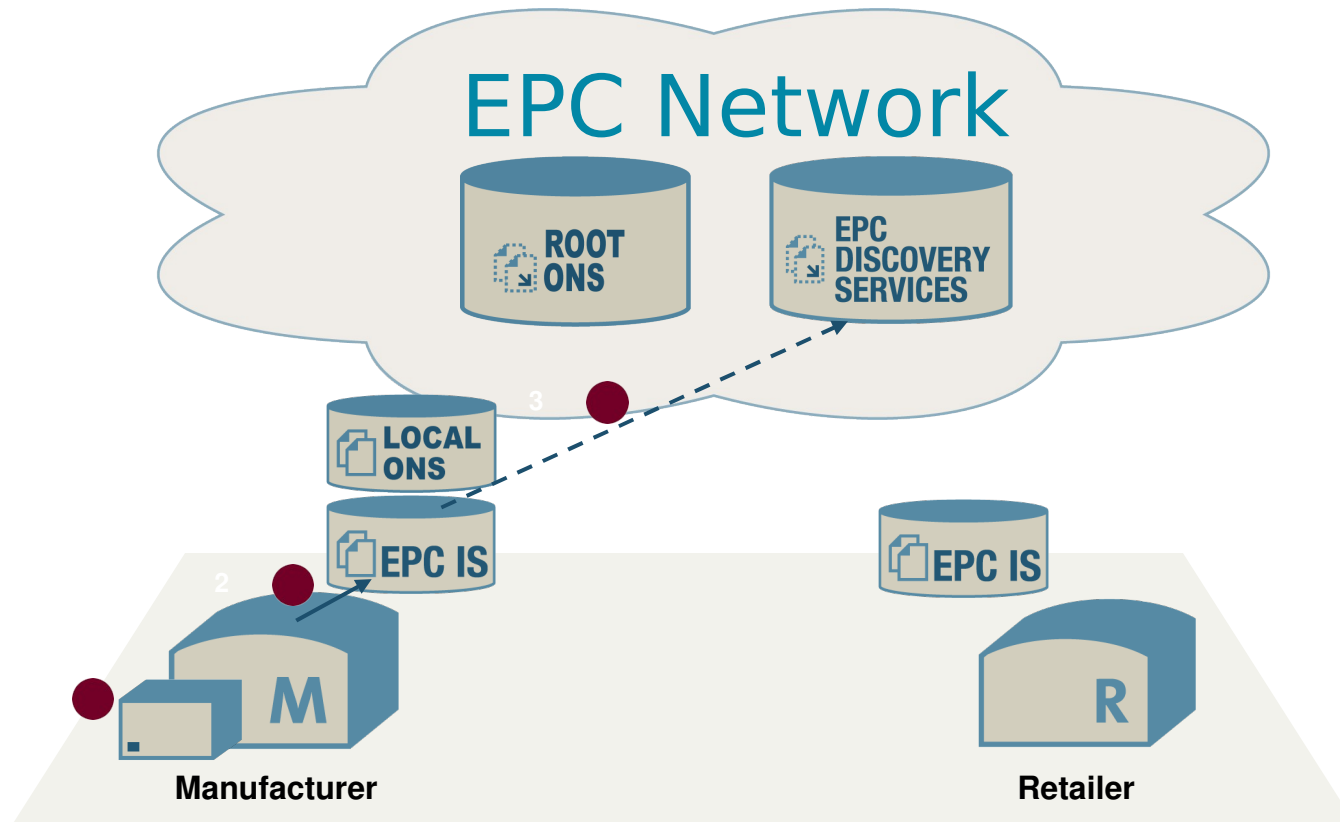


1. EPC lifecycle begins when a Manufacturer tags the product

The EPC Network

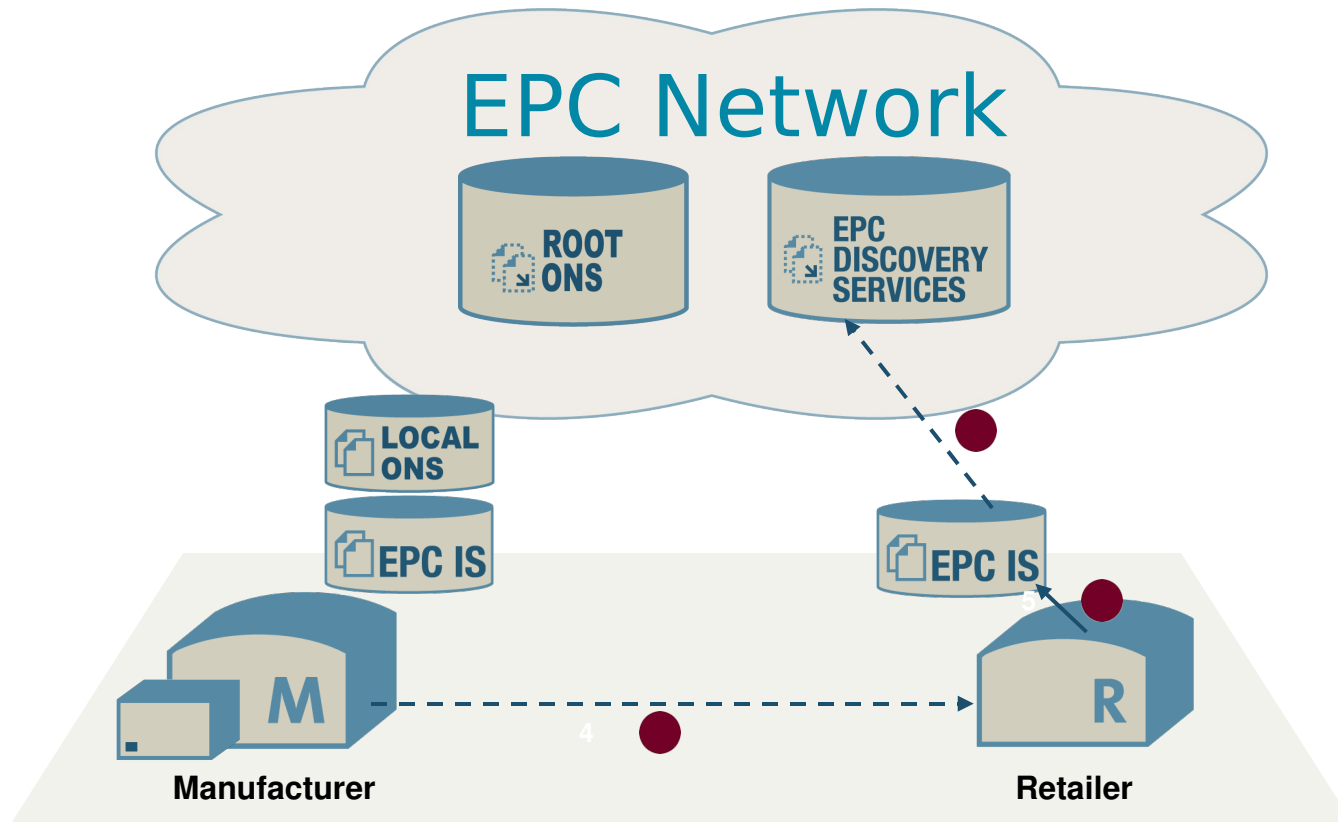


The EPC Network



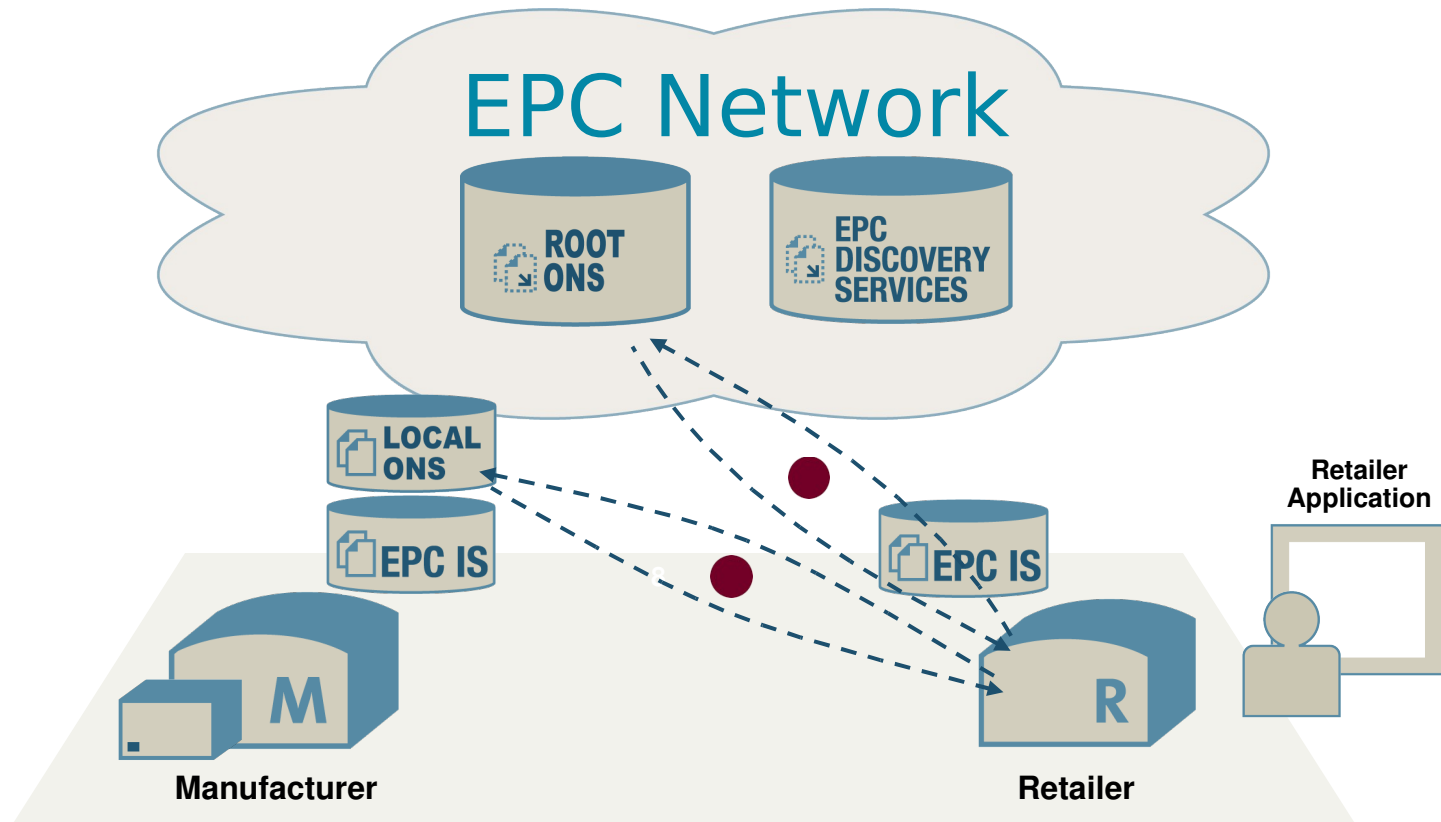
1. EPC lifecycle begins when a Manufacturer tags the product
2. Manufacturer records product information (e.g., manufacture date, expiration date, location) into EPC Information Service
3. EPC Information Service registers EPC "knowledge" with EPC Discovery Service

The EPC Network



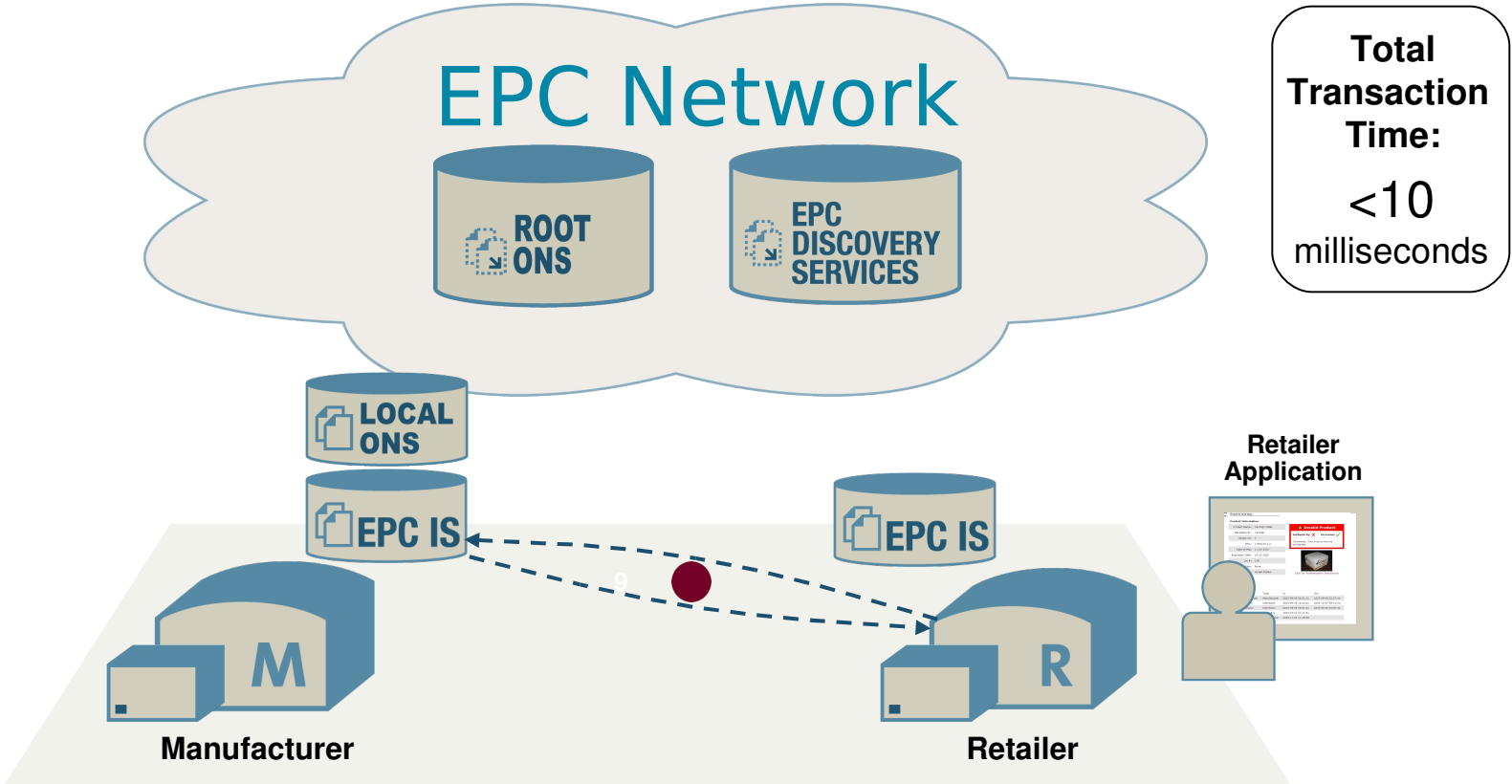
4. Manufacturer sends product to Retailer
5. Retailer records "receipt" of product into EPC-IS
6. Retailer's EPC-IS then registers product "knowledge" with EPC Discovery Service

The EPC Network



7. If Retailer requires product information, Root ONS is queried for location of Manufacturer's Local ONS
8. Manufacturer's Local ONS is queried for location of EPC-IS

The EPC Network

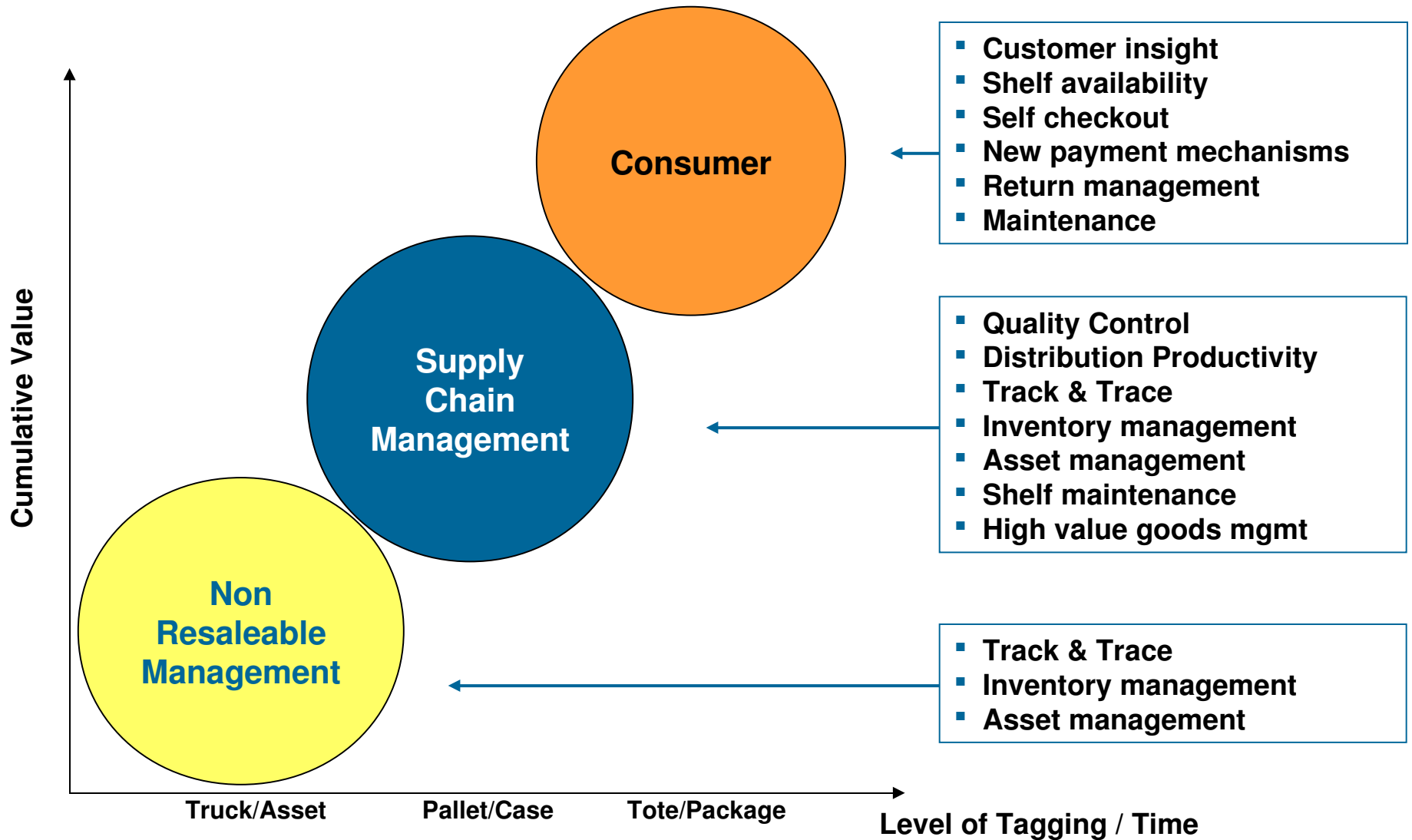


9. Retailer queries Manufacturer EPC-IS for desired product information (e.g., manufacture date, expiration date, etc.)

Outline

- Overview of RFID
 - Reader-Tag; Potential applications
- RFID Technology Internals
 - RF communications; Reader/Tag protocols
 - Middleware architecture; EPC standards
- **RFID Business Aspects**
- **Security and Privacy**
- Conclusion

Business implications of RFID tagging

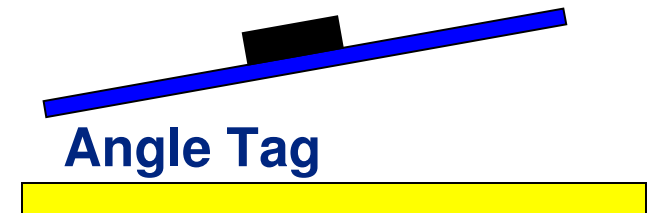
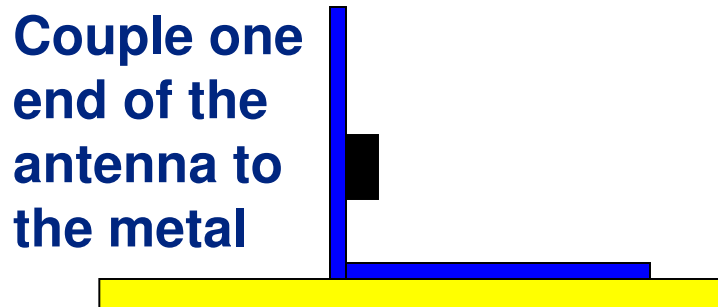


RFID deployment challenges

- Manage System costs
 - Choose the right hardware
 - Choose the right integration path
 - Choose the right data infrastructure
- Handle Material matters
 - RF Tagging of produced objects
 - Designing layouts for RF Interrogators
- Tag Identification Scheme Incompatibilities
 - Which standard to follow?
- Operating Frequency Variances
 - Low Frequency or High Frequency or Ultra High Frequency
- Business Process Redesign
 - New processes will be introduced
 - Existing processes will be re-defined
 - Training of HR
- Cost-ROI sharing

Using tags with metal

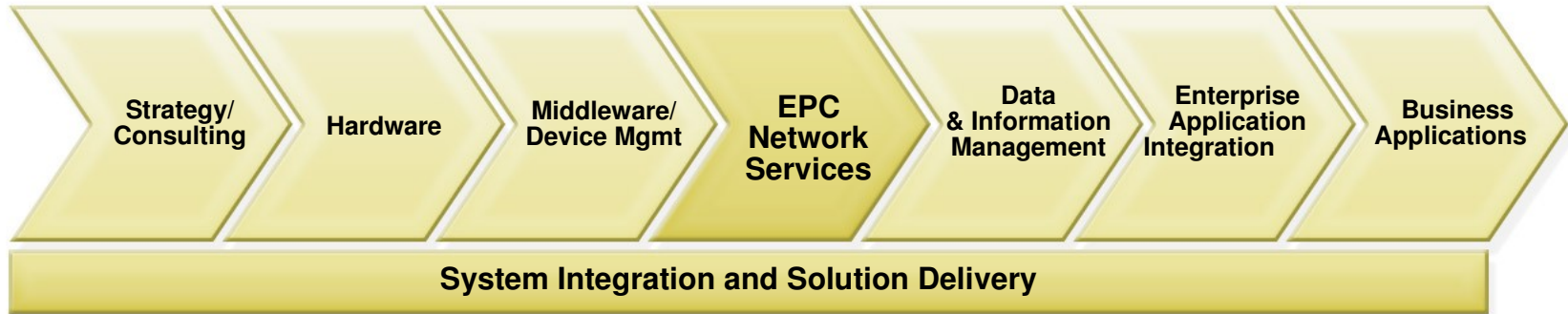
- Tags placed directly against metal will negatively affect readability



Getting ready for RFID

- Identify business process impacts
 - Inventory control (across the supply chain)
 - Manufacturing assembly
- Determine optimal RFID configuration
 - Where am I going to tag my components/products?
 - Surfaces, metal environment and handling issues
 - Where am I going to place the readers?
 - Moving from the lab environment to the manufacturing or distribution center can be tricky
 - When am I going to assemble the RFID data?
- Integrate with ERP and other systems

RFID services value chain



- Business Process Integration
 - Solution Framework
 - Network Setup
 - RF aspects
- Tags
 - Readers
 - Label Printers
- Event Monitoring
 - Data filtering
 - Reader coordination
 - Policy Management
- Directory Services
 - Discovery Services
 - Authorization / Authentication Framework
- Product Catalog and Attribute Management
 - Data Synchronization
- ETL Services
 - Legacy Application Integration
- Supply Chain Execution
 - ERP
 - Warehouse Management
 - Store Management
 - Distribution Management

Privacy: The flip side of RFID

- Hidden placement of tags
- Unique identifiers for all objects worldwide
- Massive data aggregation
- Unauthorized development of detailed profiles
- Unauthorized third party access to profile data
- Hidden readers

“Just in case you want to know, she’s carrying 700 Euro...”



The “Blocker” Tag approach

- “Tree-walking” protocol for identifying tags recursively asks question:
 - “What is your next bit?”
- Blocker tag always says ***both ‘0’ and ‘1’!***
 - Makes it seem like *all* possible tags are present
 - Reader cannot figure out which tags are actually present
 - Number of possible tags is *huge*, so reader stalls

More on blocker tags

- Blocker tag can be ***selective***:
 - *Privacy zones*: Only block certain ranges of RFID-tag serial numbers
 - *Zone mobility*: Allow shops to move items into privacy zone upon purchase
- Example:
 - Blocker blocks all identifiers with leading '1' bit
 - Items in supermarket carry leading '0' bit
 - On checkout, leading bit is flipped from '0' to '1'
 - PIN required, as for "kill" operation

The Challenge-Response approach

- Tag does not give all its information to reader.
 - The closer the reader, the more the processing.
 - Tag reveals highest level of *authenticated* information.

- 1. Reader specifies which level it wants.
- 2. Tag specifies level of security, *and/or* amount of energy needed.
- 3. Reader proceeds at that level of security.
- 4. Tag responds if and only if it gets energy and security required.

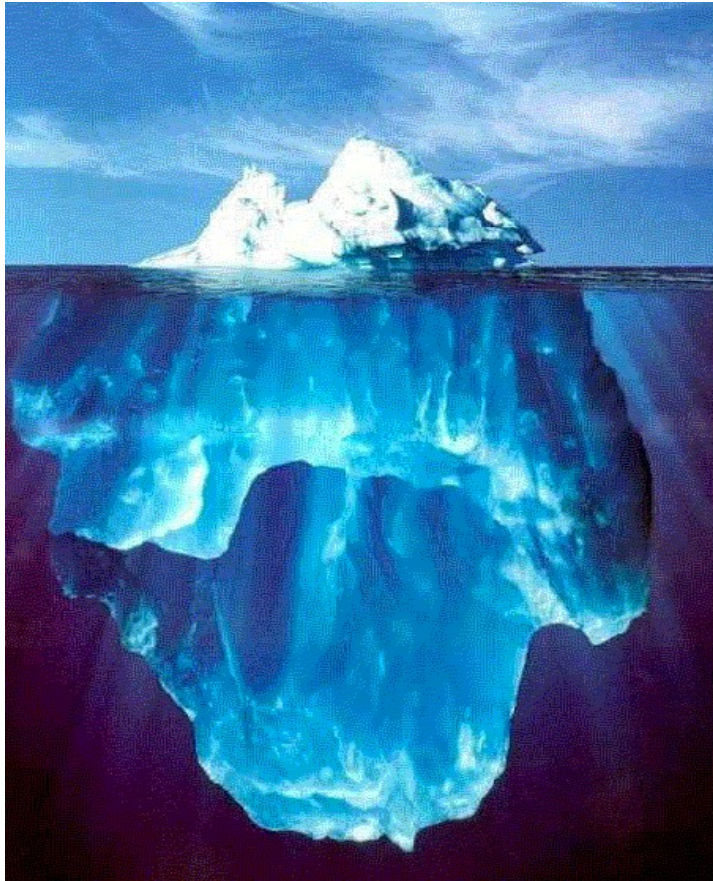
Some more approaches

- The Faraday Cage approach.
 - Place RFID tags in a protective mesh.
 - Would make locomotion difficult.
- The Kill Tag approach.
 - Kill the tag while leaving the store.
 - RFID tags are too useful for reverse logistics.
- The Tag Encryption approach.
 - Tag cycles through several pseudonyms.
 - Getting a good model is difficult.
- No 'one-size-fits-all' solution.
- Security hinges on the fact that in the real world, an adversary must have physical proximity to tags to interact with them.

Outline

- Overview of RFID
 - Reader-Tag; Potential applications
- RFID Technology Internals
 - RF communications; Reader/Tag protocols
 - Middleware architecture; EPC standards
- RFID Business Aspects
- Security and Privacy
- **Conclusion**

RFID: The complete picture



Tags and Readers

Identifying Read Points

Installation & RF Tuning

RFID Middleware

Connectors & Integration

Process Changes

Cross Supply-Chain View

Points to note about RFID

- RFID benefits are due to automation and optimization.
- RFID is not a plug & play technology.
- “One frequency fits all” is a myth.
- Technology is evolving but physics has limitations.
- RFID does not solve data inconsistency within and across enterprises.
- Management of RFID infrastructure and data has been underestimated.

RFID Summary

<h2>Strengths</h2> <ul style="list-style-type: none">➤ Advanced technology➤ Easy to use➤ High memory capacity➤ Small size	<h2>Weaknesses</h2> <ul style="list-style-type: none">➤ Lack of industry and application standards➤ High cost per unit and high RFID system integration costs➤ Weak market understanding of the benefits of RFID technology
<h2>Opportunities</h2> <ul style="list-style-type: none">➤ Could replace the bar code➤ End-user demand for RFID systems is increasing➤ Huge market potential in many businesses	<h2>Threats</h2> <ul style="list-style-type: none">➤ Ethical threats concerning privacy life➤ Highly fragmented competitive environment

Some Links

- <http://www.epcglobalinc.com/>
- <http://www.rfidjournal.com/>
- <http://rfidprivacy.com/>
- <http://www.rfidinc.com/>
- <http://www.buyrfid.com/>

Thank You

