RFID Applications:
Paradigm change and its collateral effects on Middleware
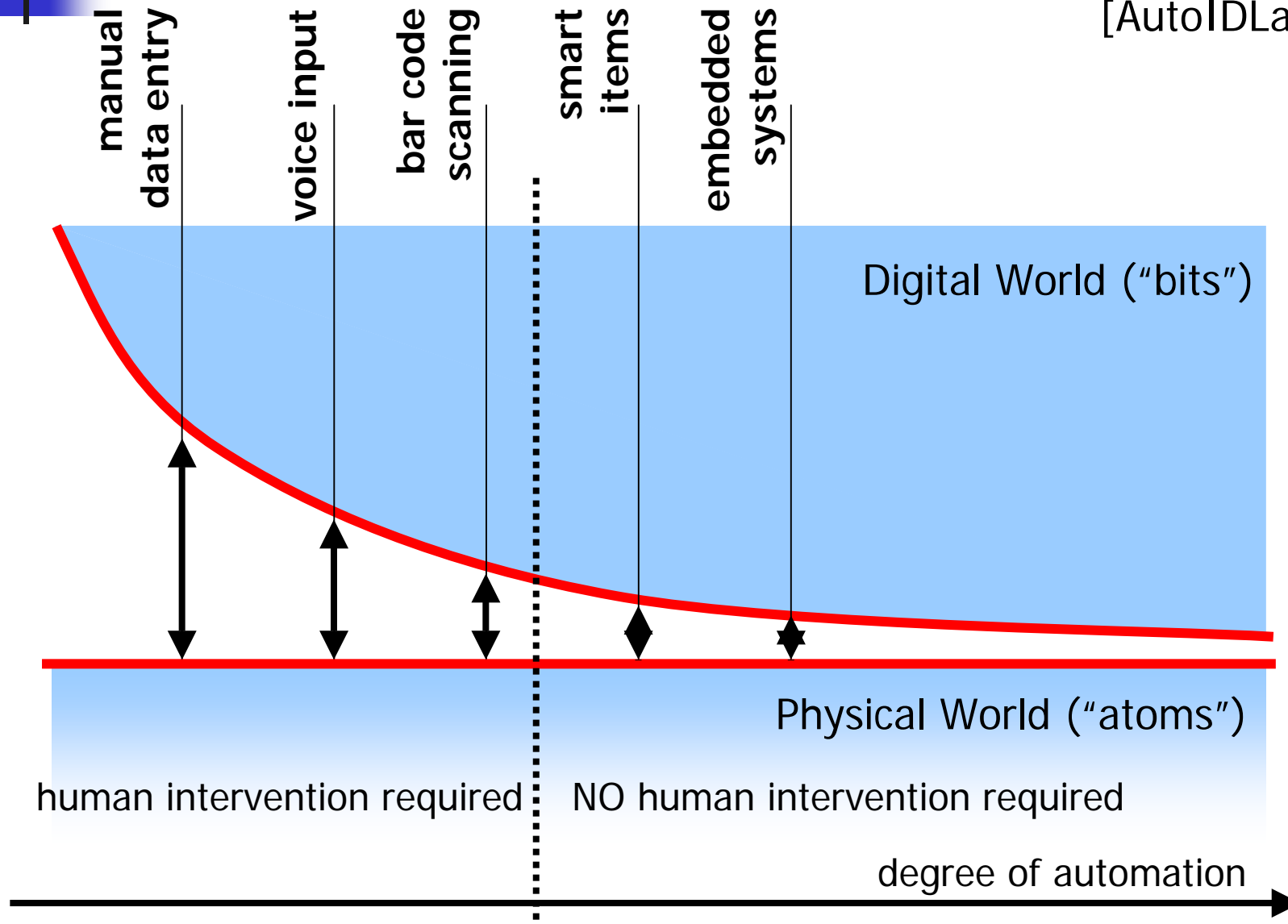
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Physical & Digital Worlds

manual data entry

voice input

bar code scanning

smart items

embedded systems

Digital World ("bits")

Physical World ("atoms")

human intervention required

NO human intervention required

degree of automation

RFID – Use cases

- **Badges/Smart keys**
  - Grant or deny access
- **Agriculture**
  - Animal tracking
- **Toll roads**
  - Tracking and charging
- **Asset Management**
  - Tracking of rack-mounted devices in large comp-centers
- **Maintenance**
  - Aircraft – intelligent toolbox, catering cart tracking
- **Supply Chain Mgmt**
  - Inventory control
  - Logistics, tracking and tracing
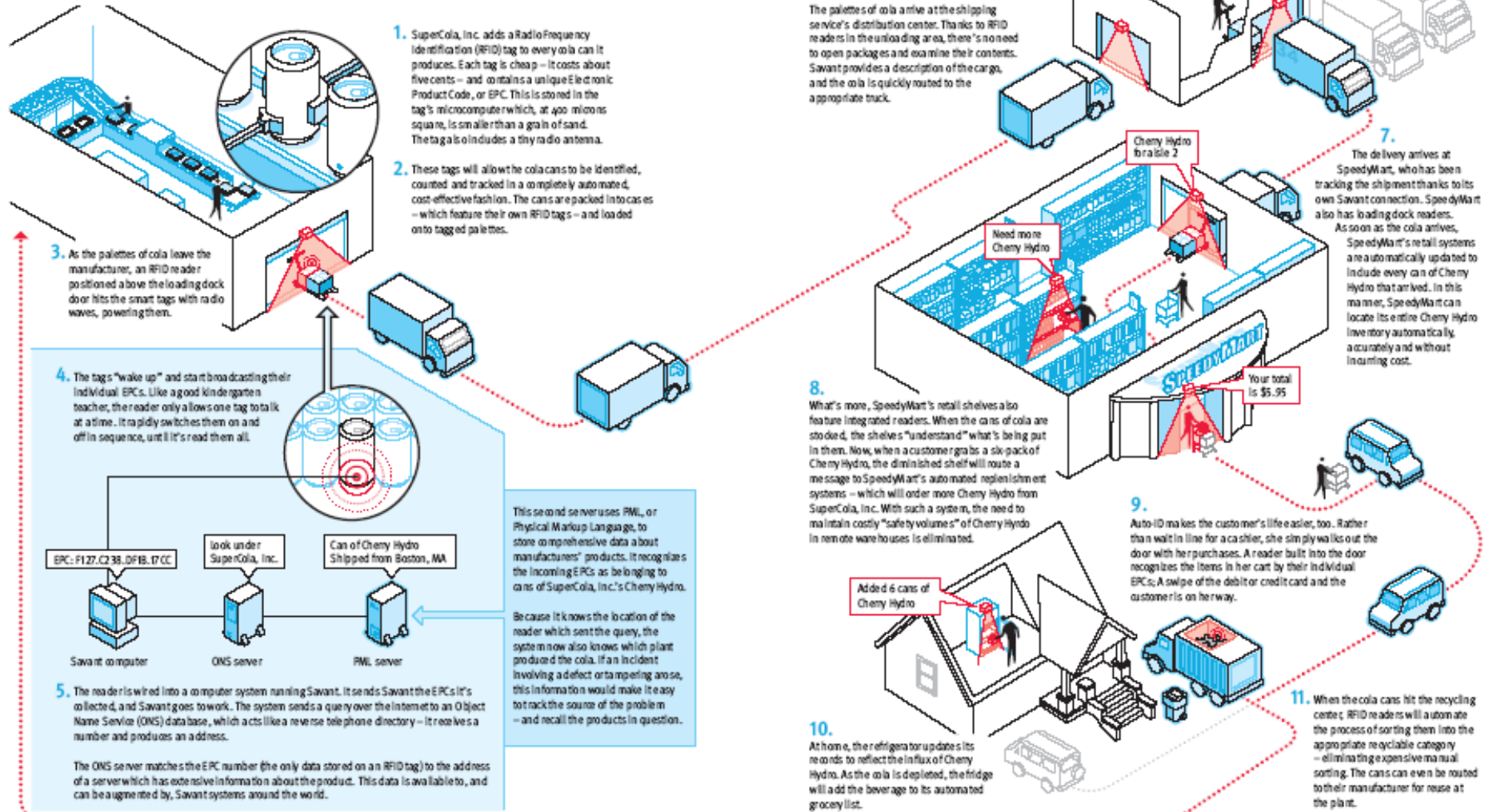
RFID & Supply Chain Mgmt

- Innovate ways to identify, locate and monitor goods as they travel through the supply chain of many industries

- First Benefits (business view)
  - Increase accuracy of orders
  - Reduce inventory handling cost
    - Improve inventory handling
  - Fewer misplaced items (in warehouse)
  - Reduce losses from theft (ca. $31 Bi in 2002)
  - Real-time enterprise / Information on-demand
  - ...

RFID & Supply Chain Mgmt (cont)

HOW THE AUTO-ID SYSTEM WILL AUTOMATE THE SUPPLY CHAIN

XPLANATIONS™ by XPLANE®

With Auto-ID technology, physical objects will have embedded intelligence that will allow them to communicate with each other and with businesses and consumers. Auto-ID technology offers an automated, numeric system of smart objects that revolutionizes the way we manufacture, sell, and buy products. Here's how it works:
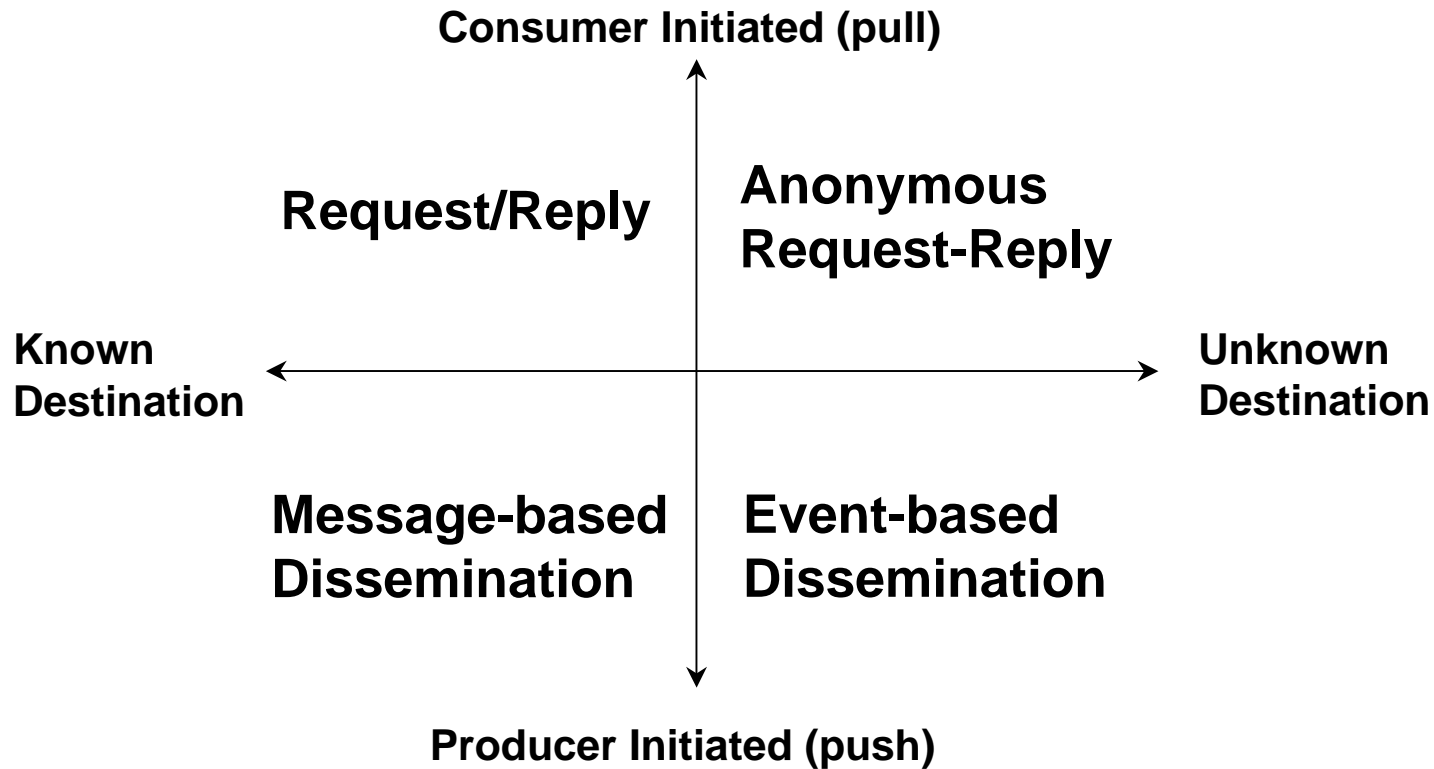
1. SuperCola, Inc. adds a Radio Frequency Identification (RFID) tag to every cola can it produces. Each tag is cheap – it costs about five cents – and contains a unique Electronic Product Code, or EPC. This is stored in the tag's microcomputer which, at 400 microns square, is smaller than a grain of sand. The tag also includes a tiny radio antenna.

2. These tags will allow the cola cans to be identified, counted and tracked in a completely automated, cost-effective fashion. The cans are packed into cases – which feature their own RFID tags – and loaded onto tagged palettes.

3. As the palettes of cola leave the manufacturer, an RFID reader positioned above the loading dock door hits the smart tags with radio waves, powering them.

4. The tags "wake up" and start broadcasting their individual EPCs. Like a good kindergarten teacher, the reader only allows one tag to talk at a time. It rapidly switches them on and off in sequence, until it's read them all.

EPC: F127.C238.DF1B.17CC

look under SuperCola, Inc.

Can of Cherry Hydro Shipped from Boston, MA

Savant computer

ONS server

PML server

This second server uses PML, or Physical Markup Language, to store comprehensive data about manufacturers' products. It recognizes the incoming EPCs as belonging to cans of SuperCola, Inc.'s Cherry Hydro.

Because it knows the location of the reader which sent the query, the system now also knows which plant produced the cola. If an incident involving a defect or tampering arose, this information would make it easy to track the source of the problem – and recall the products in question.

5. The reader is wired into a computer system running Savant. It sends Savant the EPCs it's collected, and Savant goes to work. The system sends a query over the internet to an Object Name Service (ONS) database, which acts like a reverse telephone directory – it receives a number and produces an address.

The ONS server matches the EPC number (the only data stored on an RFID tag) to the address of a server which has extensive information about the product. This data is available to, and can be augmented by, Savant systems around the world.

6. The palettes of cola arrive at the shipping service's distribution center. Thanks to RFID readers in the unloading area, there's no need to open packages and examine their contents. Savant provides a description of the cargo, and the cola is quickly routed to the appropriate truck.

Cherry Hydro, send to truck 34

Cherry Hydro for aisle 2

Need more Cherry Hydro

7. The delivery arrives at SpeedyMart, who has been tracking the shipment thanks to its own Savant connection. SpeedyMart also has loading dock readers. As soon as the cola arrives, SpeedyMart's retail systems are automatically updated to include every can of Cherry Hydro that arrived. In this manner, SpeedyMart can locate its entire Cherry Hydro inventory automatically, accurately and without incurring cost.

8. What's more, SpeedyMart's retail shelves also feature integrated readers. When the cans of cola are stocked, the shelves "understand" what's being put in them. Now, when a customer grabs a six-pack of Cherry Hydro, the diminished shelf will route a message to SpeedyMart's automated replenishment systems – which will order more Cherry Hydro from SuperCola, Inc. With such a system, the need to maintain costly "safety volumes" of Cherry Hydro in remote warehouses is eliminated.

Your total is $5.95

9. Auto-ID makes the customer's life easier, too. Rather than wait in line for a cashier, she simply walks out the door with her purchases. A reader built into the door recognizes the items in her cart by their individual EPCs; A swipe of the debit or credit card and the customer is on her way.

Added 6 cans of Cherry Hydro

10. At home, the refrigerator updates its records to reflect the influx of Cherry Hydro. As the cola is depleted, the fridge will add the beverage to its automated grocery list.

11. When the cola cans hit the recycling center, RFID readers will automate the process of sorting them into the appropriate recyclable category – eliminating expensive manual sorting. The cans can even be routed to their manufacturer for reuse at the plant.

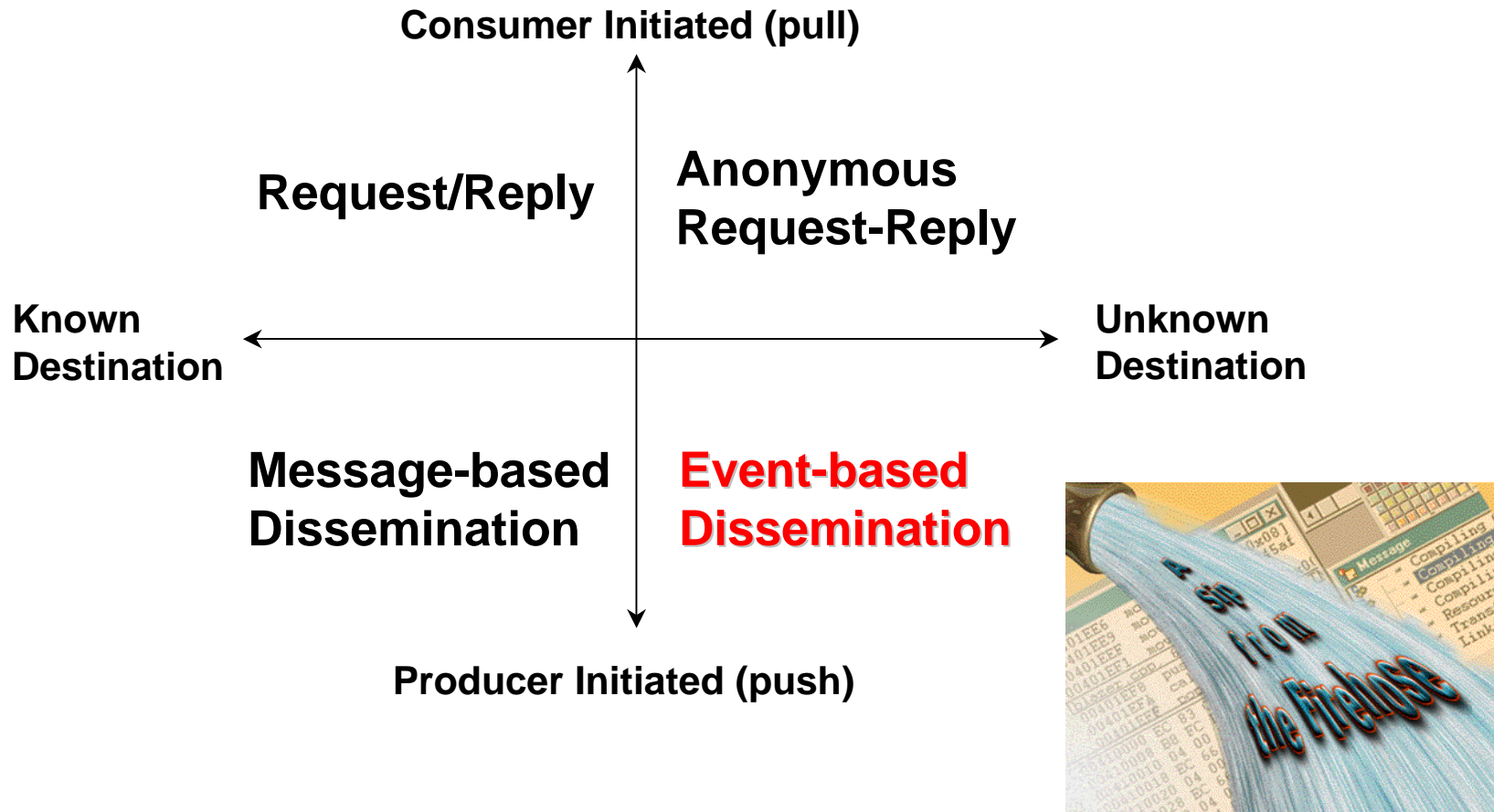©2002 XPLANE.com®

Traditional Applications

- **Basically based on Request/Reply**
  - Client application requests for data on a well-known source/database
    - It fits
      - the imperative nature of C/S paradigm
      - programming language abstraction

- **Direct and synchronous communications**
  - Enforces tightly coupling of communication parties
  - Limits scalability

- **Clients pull remote data sources**
  - Trade-off when data is dynamic
    - Polling limits accuracy of data
      - Short polling interval → waste resource
      - Long polling interval → increase update latency
        - Unnecessary resource consumption

- **Need for asynchronous and decoupled operations**

Modes of Interaction – Paradigm Change

Consumer Initiated (pull)

Request/Reply

Anonymous Request-Reply

Known Destination

Unknown Destination

Message-based Dissemination

Event-based Dissemination

Producer Initiated (push)

Modes of Interaction – Paradigm Change

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**Message-based
Dissemination**

**Event-based
Dissemination**

Producer Initiated (push)

**Information flows from
producer to consumer**

RFID & Supply Chain Mgmt (cont)

- **ePC & RFID**
  - **ePC** is stored in a RFID-Tag
  - Reader gets the message (**ePC**)
  - **ePC** needs to be **disseminated** and processed
    - Workflow, ERP, etc.
- **It imposes challenges on the IT infrastructure**
  - Data processing
    - Online handling of huge amounts of **streaming data**
    - Storage, network bandwidth & systems
  - Integration
    - DBs, data warehouses and enterprise apps

Middleware/Infrastructure

- **From the software point of view**
  - Data is no longer static: streams of data!
  - Data exchange across enterprise boundaries:
    - Data is generated along the supply chain
    - Transactions (workflows, etc)
    - Privacy aspects (who consumes which data)
  - Data needs to be disseminated proactively
    - From data producers to data consumers
    - 1-to-many communications

- **Traditional Middleware (Request/reply) does not fit**

- **Event handling infrastructure is required**

AutoID Software Infrastructure
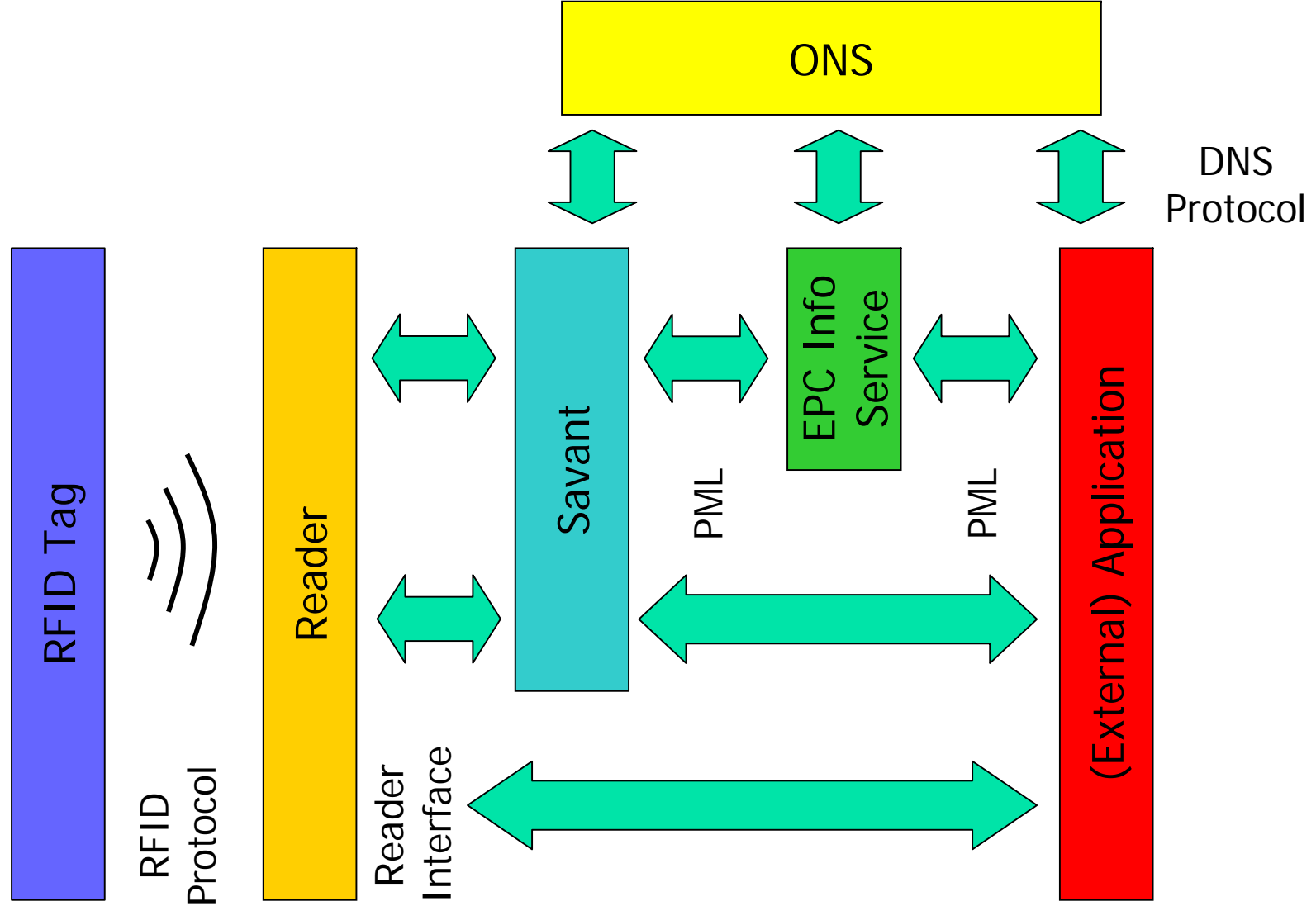
Savant

- Savant is the middleware component of the EPC Network

- Savant processes and distributes data/event streams

- Processing consists of filtering and aggregating

- Savant is a container for processing modules: standard and user-defined

- Version 1.0 only contains 2 standard modules: core and readerproxy

- Key point 1: readerproxy queries reader peripherals

- Key point 2: filtering and aggregation not implemented in Savant 1.0

SAP's Auto-ID Architecture
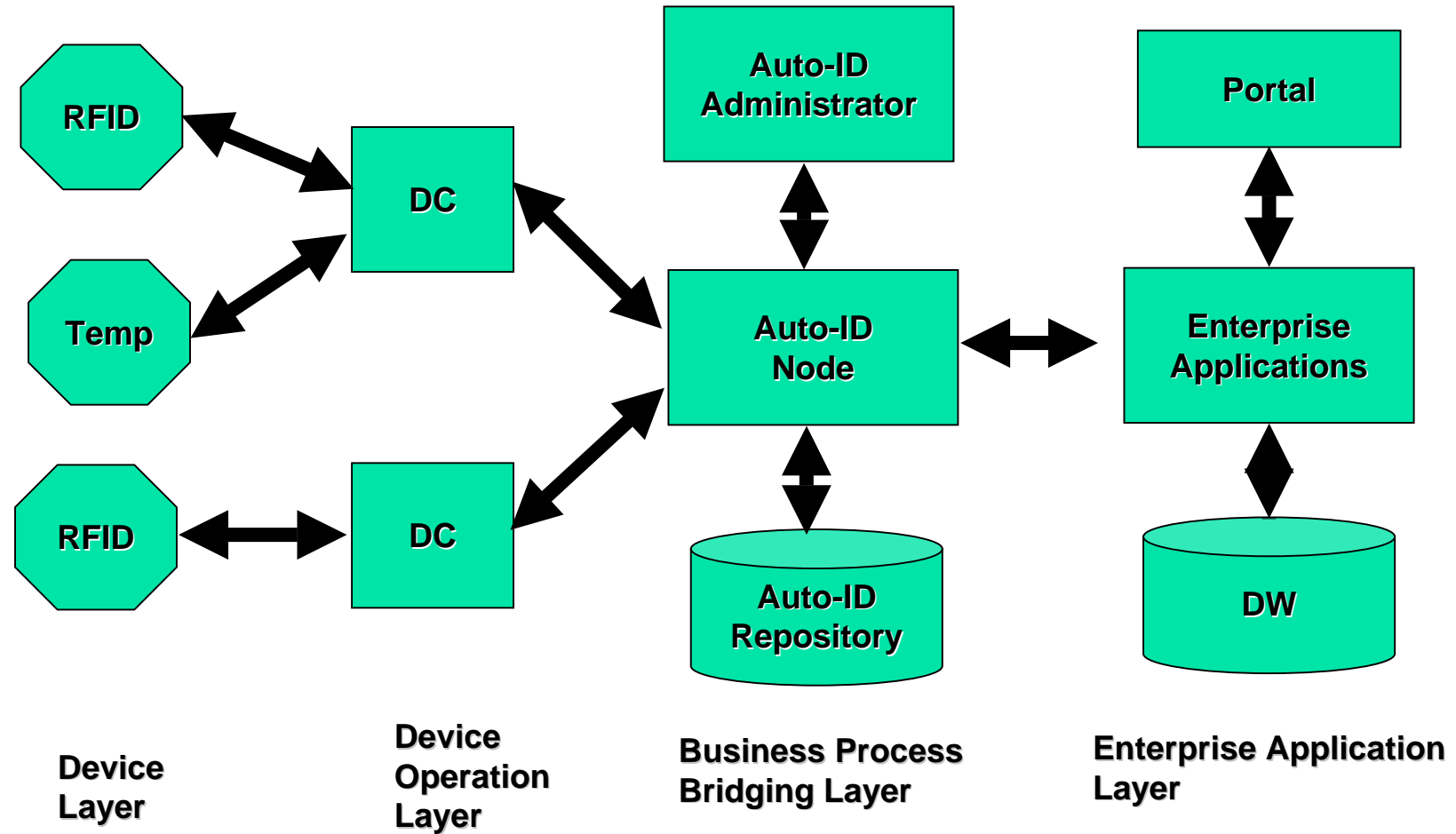
Challenges in RFID – Auto-ID Technology

- Scalability: throughputs of 60 billion items/yr, 100 msg/sec, 200 Bytes/msg, multiple DB updates/msg and multiple business proc./msg
- Efficient event filtering: duplicate elimination, selective message propagation
- Event aggregation: composition of related events (n objects/pallet, temp over time, temp/position/object ID)
- Flexible response at the business logic layer
- Distribution of system functionality: move filtering, aggregation and part of business logic to periphery
- System administration and test support

From RFID to Sensor Nodes – Convergence of Technologies

- Four classes of tags
  - passive transponders without memory (class 1)
  - passive transponders with memory (class 2)
  - semiactive transponders with on-board battery (class 3)
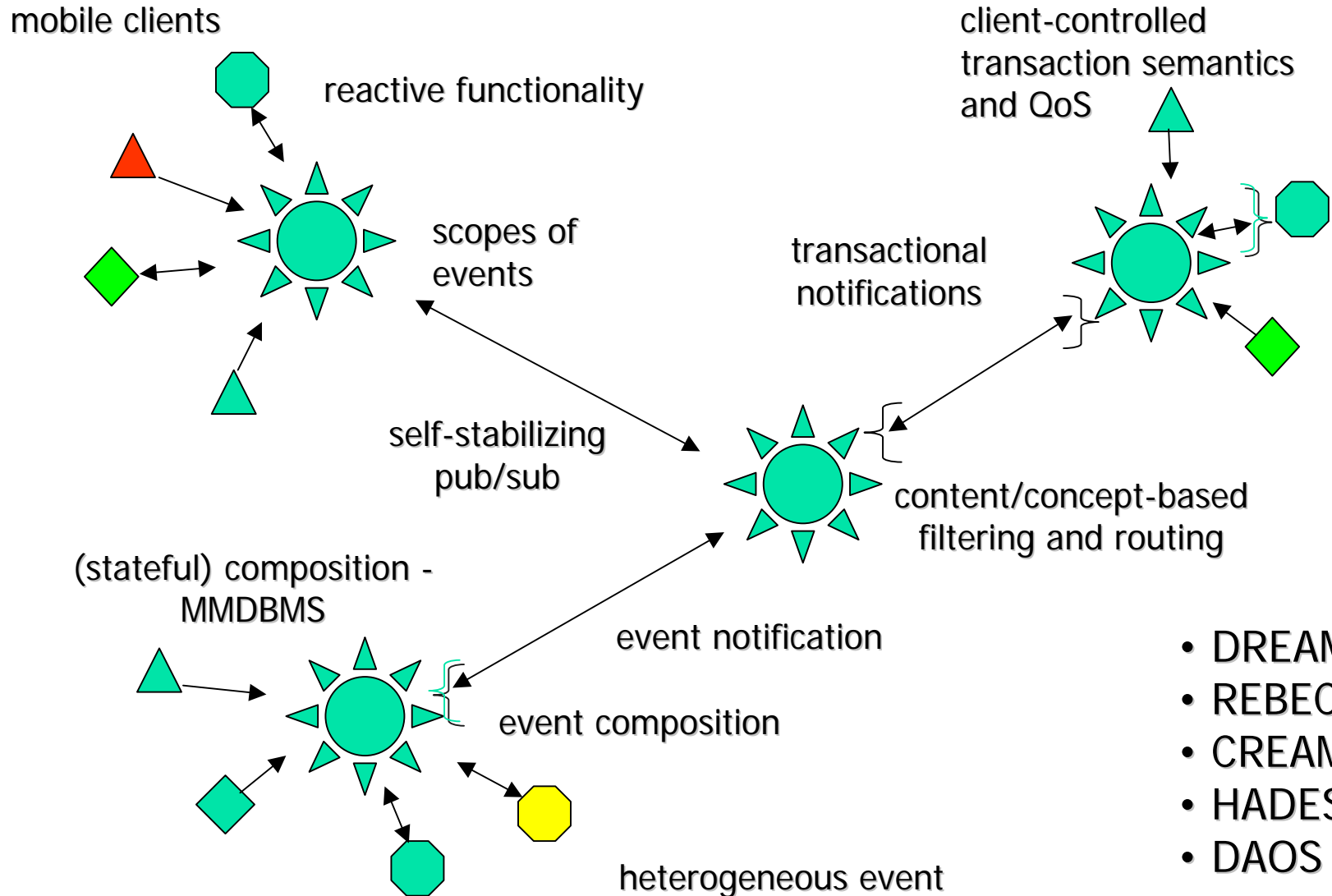 - active transponders with integrated sensors (class 4)
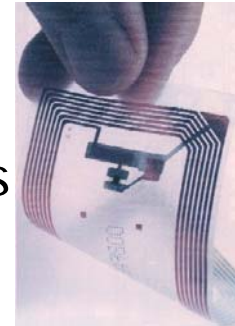
- Auto-ID Center developed base architecture and standards for passive RFID tags

- Research community has been moving fast Wireless Sensor Networks (WSN) – mostly sponsored by DoD
- RFID tags are converging to WSN nodes

DOT   MICA
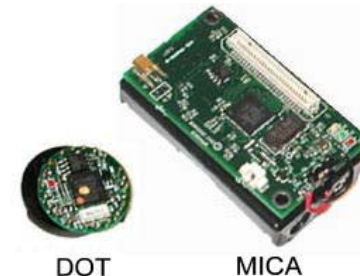
→ middleware must cope with whole range

Event Handling Infra - Overview

mobile clients

reactive functionality

client-controlled
transaction semantics
and QoS

scopes of
events

transactional
notifications

self-stabilizing
pub/sub

content/concept-based
filtering and routing

(stateful) composition -
MMDBMS

event notification

event composition

heterogeneous event

- DREAM
- REBECA
- CREAM
- HADES
- DAOS

Experience

- **Heterogeneous data integration**
- **Notification Services**
  - multi-hop transactions
  - routing efficiency
  - scopes
  - mobility support
  - scalability (P2P), ...
- **Reactive Functionality**
- **Benchmarking for Enterprise Apps (J2EE)**
- **Workflow (& Web Services)**

Performance

- Performance is a critical issue of Auto-ID sytems

- Must reconsider architecture
  - move business logic to periphery (rule-engine on low-capability devices!!!)
  - move from RPC-like interactions to pub/sub

- Must benchmark existing systems

Ongoing Work – Benchmarking

- **Simulation platform**
  - Distributed injection of events
  - Different load generation levels
  - Data generation based on different distributions and scripts
  - Fault injection
  - Flexible data structures
- **Also valid for stress tests on notification services**

Ongoing Work – WSN Middleware

- **Active RFID**
  - WSN
  - Data is no longer aggregated at the edge (RFID readers)
- **Event-based infrastructure**
  - Additional challenges
    - Energy consumption
    - Broadcast-based networks
    - On-network aggregation
    - High rate of failures

Conclusions

- RFID and WSN are converging
- Current Auto-ID technology must be expanded to include
  - push-based communication
  - better event aggregation (at the periphery)
  - business logic at the periphery
- Benchmarks for expanded RFID technology and Auto-ID infrastructures are sorely needed