LIT Middleware: Design and Implementation of RFID Middleware based on the EPC Network Architecture

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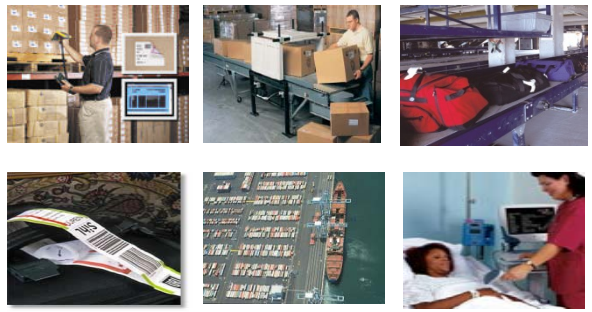
Introduction

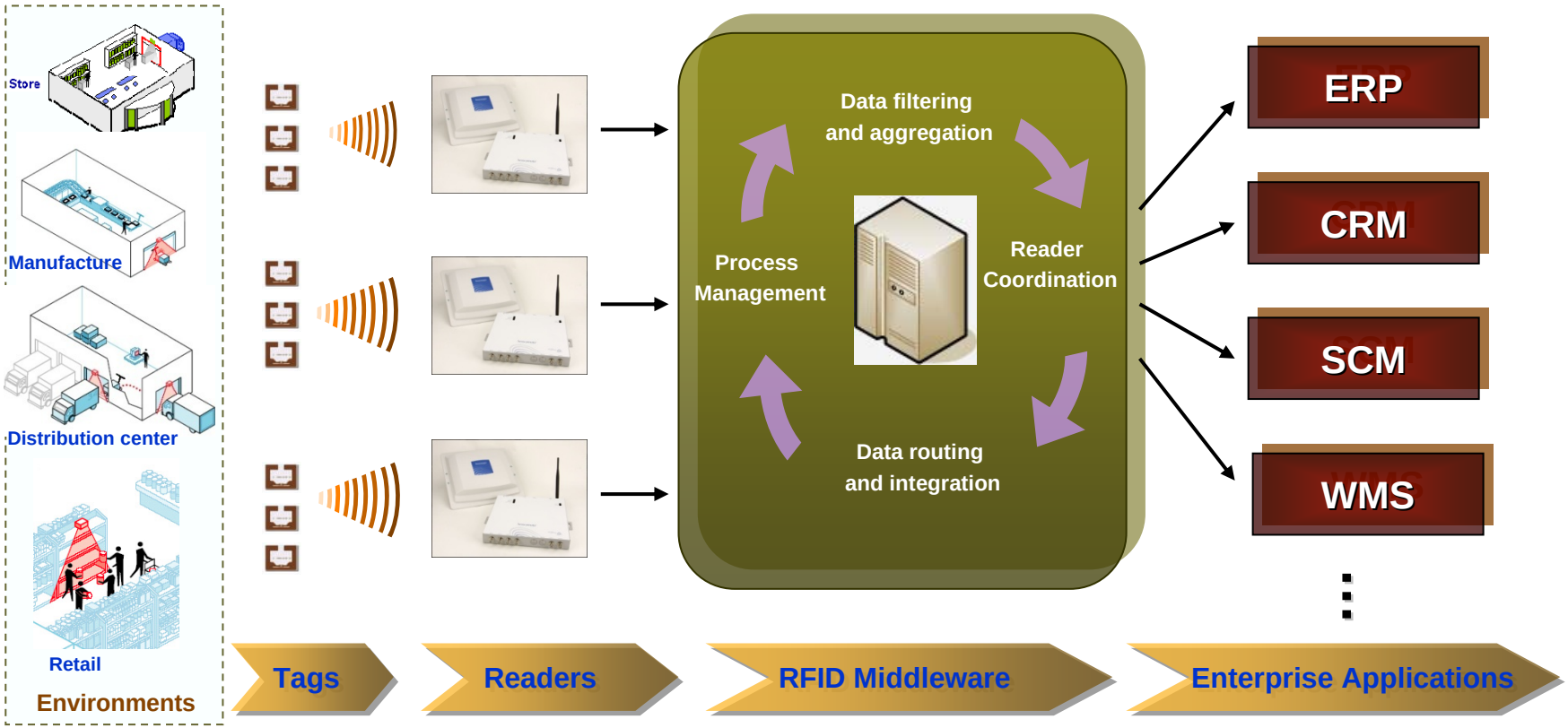
- **RFID Middleware needed for**
  - Track & Trace item automatically throughout the supply chain.
  - Safe & Secure supply chain.
  - Fast & Accurate data collection.
  - Business process automation.

- **Application Domains**
  - Supply Chain Management (SCM) in transportation
  - e-Government
  - e-Health
  - Waste management
  - Documents identification & tracking

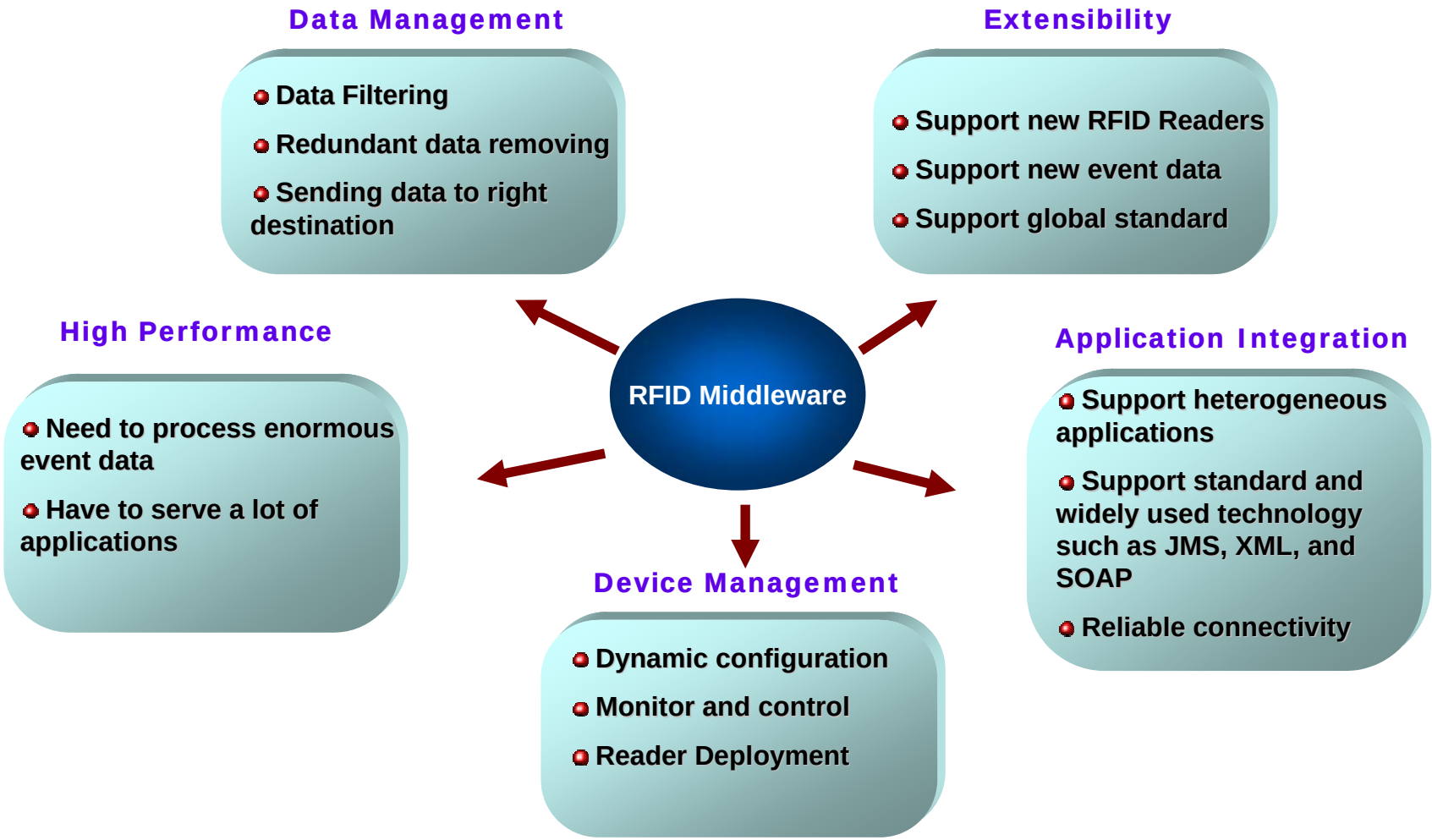


Introduction

- **RFID Middleware**
  - Process real time event data



Requirements of RFID Middleware

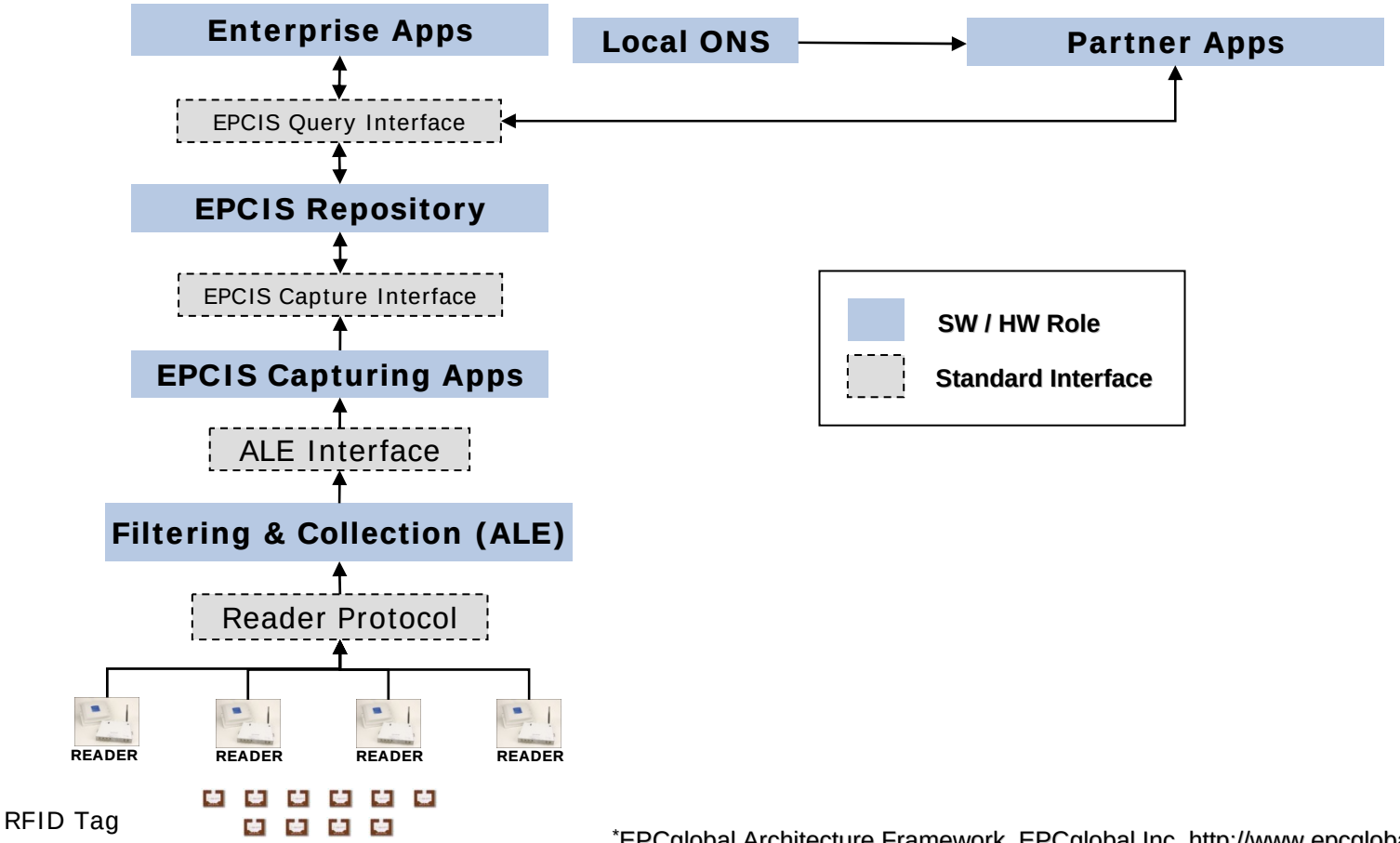


Standard for RFID Middleware

- ☑ **EPCglobal Standard**
  - Joint venture between EAN international and UCC Inc.
  - Developed by Auto-ID center
  - Objectives
    - Achieving worldwide adoption and standardization of EPC technology
  - Suggests
    - EPC network architecture for RFID technology
      - Standard for RFID Middleware
    - Roles and Interfaces
    - Standard Data format
  - Benefits
    - True visibility of items in supply chain
    - More accurate and immediate information

Standard for RFID Middleware

☑ Overview of EPC Network Architecture*



*EPCglobal Architecture Framework, EPCglobal Inc. http://www.epcglobalinc.org

Standard for RFID Middleware

- **Roles of Application Level Events (ALE)**
  - Receiving EPCs from one or more data sources
  - Accumulating, filtering and grouping EPCs
  - Reporting in various forms

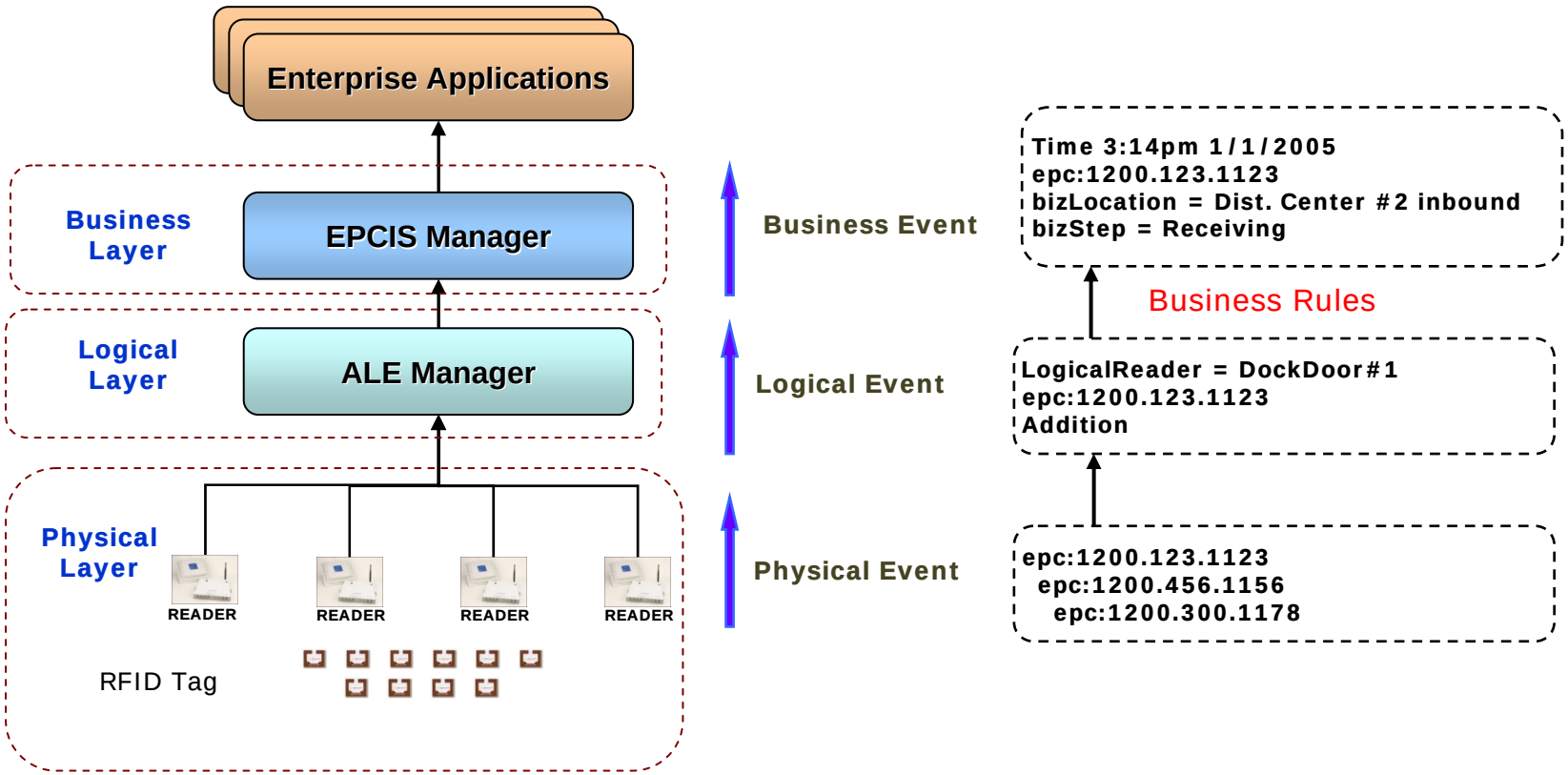
- **Roles of EPC Information Services (EPCIS)**
  - Store biz events
  - Respond queries from various clients
  - Provides a uniform programmatic interface to various clients

Overview of LIT Middleware

- **Objectives of LIT Middleware**
  - To provide highest level of extensibility
  - To provide fast & accurate data collection
  - To support heterogeneous applications
  - To support diverse logistics devices
- **Layered Architecture**
  - Physical Layer
    - RFID tag & Reader
  - Logical Layer
    - ALE Manager
      - Standard reader interface and reader integration module
      - Smoothing filter & Continuous Query Processor
  - Business Layer
    - EPCIS Manager
      - Data Source Access Component
      - Continuous query processor
      - Track & Trace query module

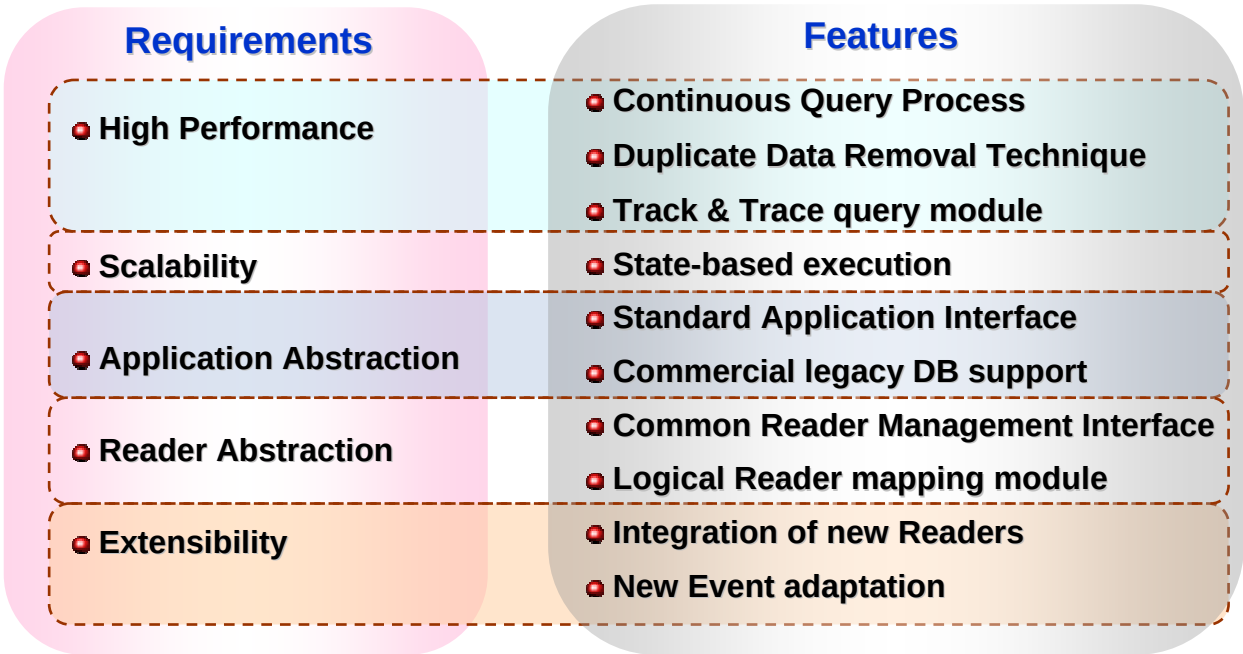
Overview of LIT Middleware

☑ Top level Architecture of LIT Middleware



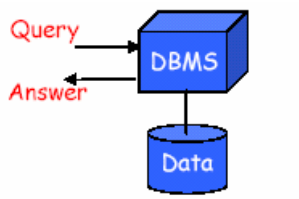
Design concepts of LIT Middleware

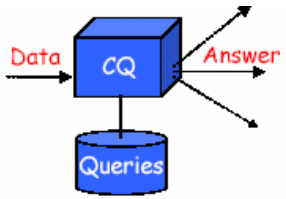
- **Features from Requirements**
  - Analyzed Requirements of Middleware
  - Analyzed EPCglobal Standard
  - Deduced Features of Middleware

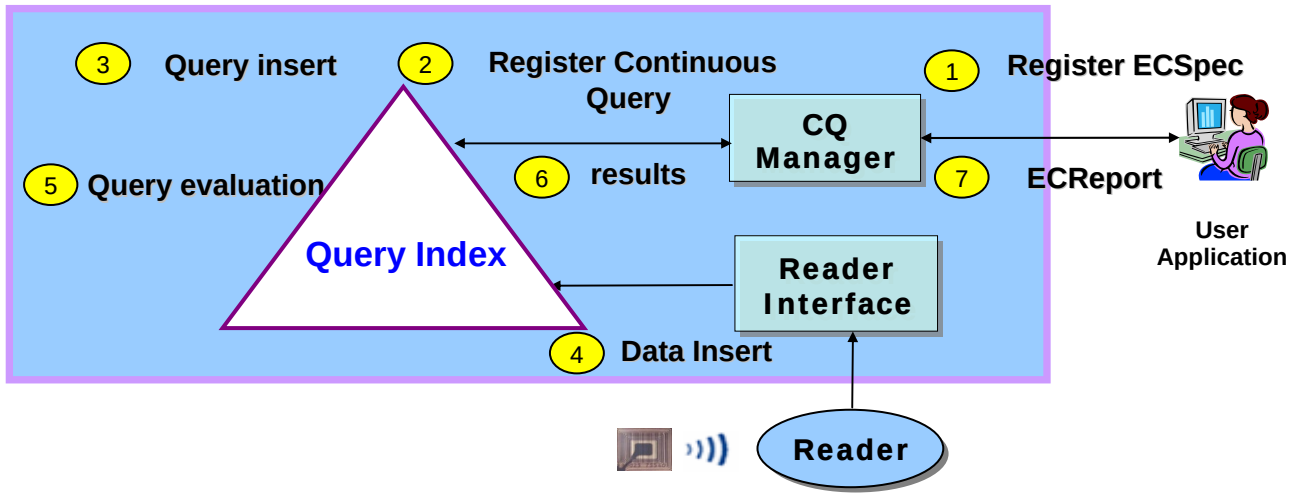


Features of ALE Manager

- **High performance**
  - Continuous Query Process
    - RFID data are gathered continuously by many readers
    - EPCglobal mentions standard specification (ECSpec) for filtering and collecting data during fixed time interval
    - Query Index – representing query using spatial data structure

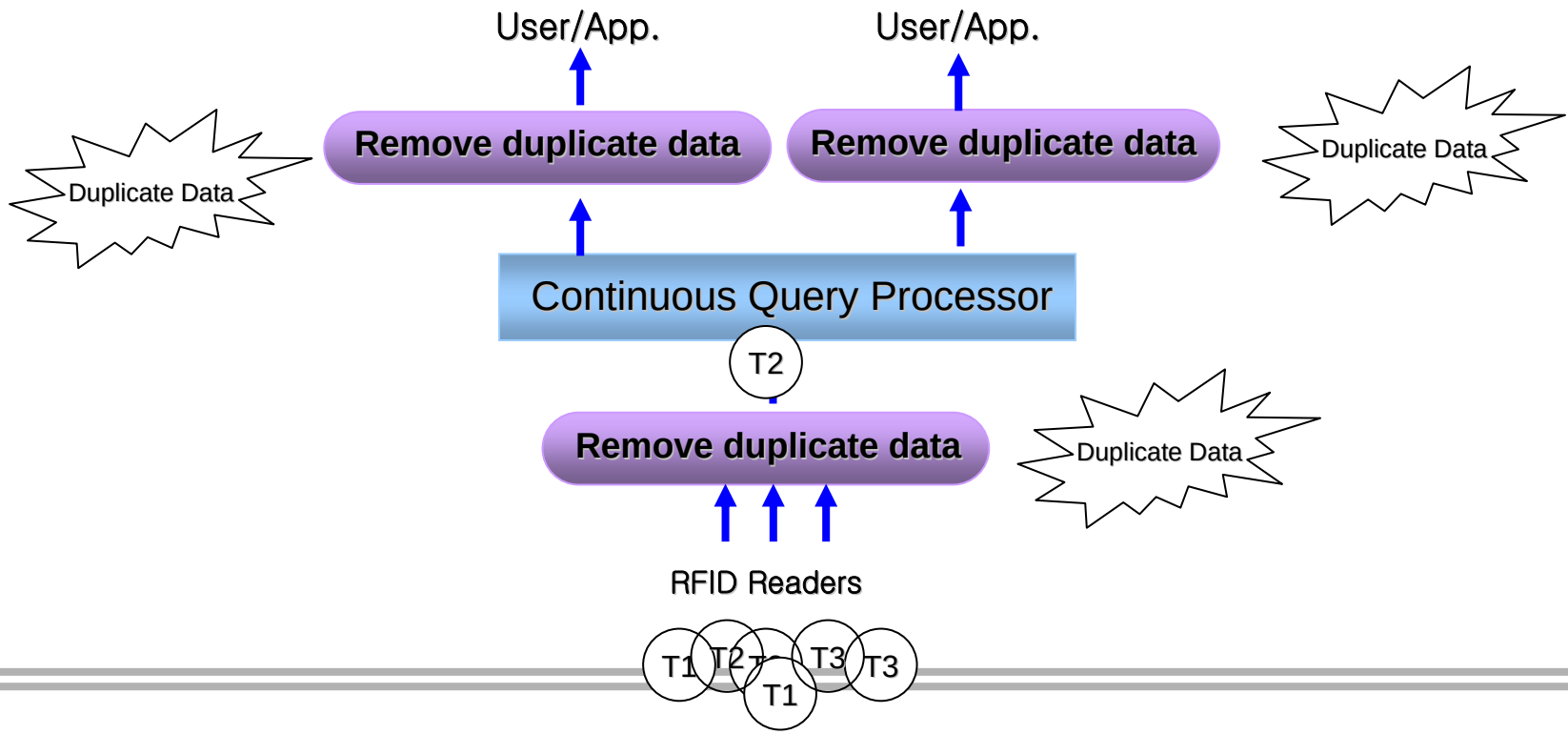






Features of ALE Manager

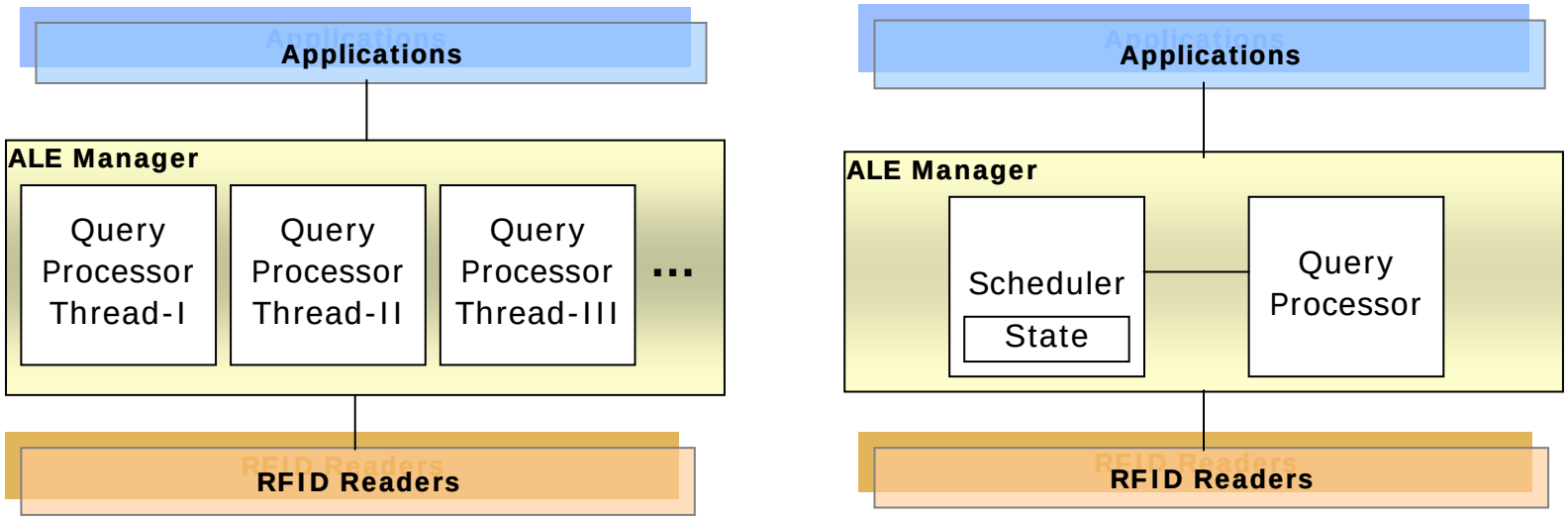
- ☑ **High performance**
  - ➢ Duplicate data removal technique
    - ● Time duration of each query called event cycle.
    - ● During event cycle reader may read same tag many times



Features of ALE Manager

☑ Scalability

- Thread-based execution VS. State-based execution*
- Thread-based execution model incurs significant overhead due to
  - Cache misses
  - Lock contention
  - Switching
- State-based execution model
  - Single scheduler
  - Avoids the limitation of thread-based model



*Operator Scheduling in a Data Stream Manager. *29th VLDB Conference, Berlin, Germany, pp 838-849*

Features of ALE Manager

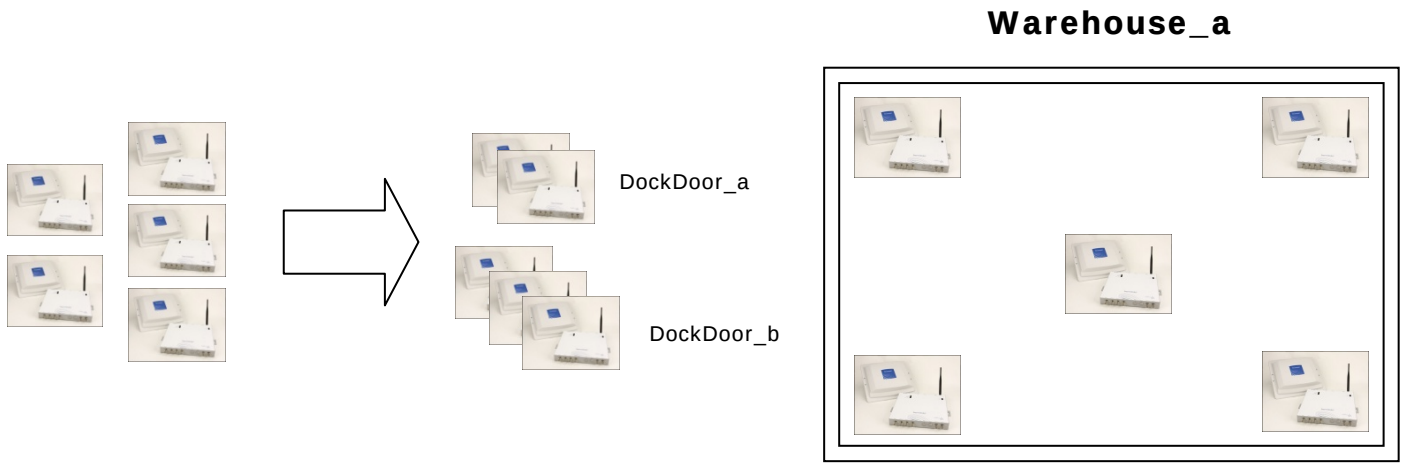
- ☑ **Application Abstraction**
  - ➢ Provides independence from different types of applications
  - ➢ EPCglobal proposed extensible application interface
    - ● API for Management
      - – API for Reader Management
      - – API for Middleware Management
    - ● API for Query
      - – Define, Undefine, Subscribe, Unsubscribe
      - – Immediate, Poll
  - ➢ Common Application Query & Response (by EPCglobal)
    - ● ECSpec, ECReports

Features of ALE Manager

☑ Reader Abstraction

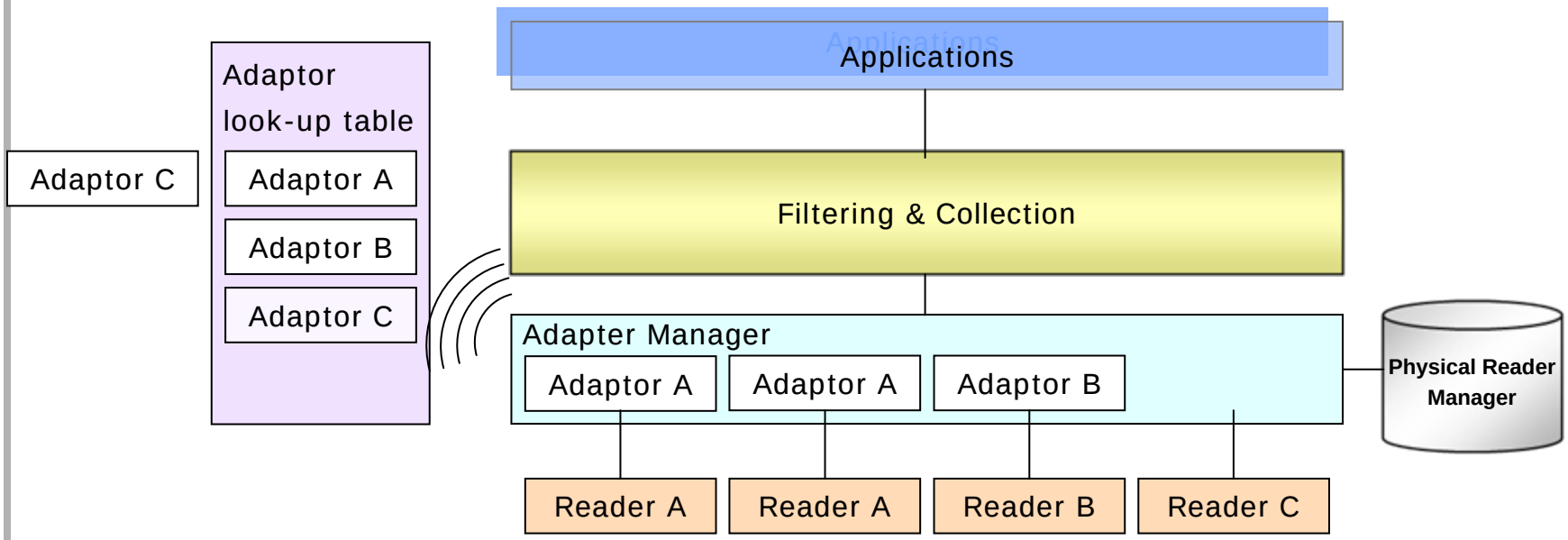
- Common Reader Management Interface
  - Manage heterogeneous RFID Reader
  - Using EPCglobal Reader Protocol standard

- Logical Reader Mapping
  - Independent from
    - Number of RFID Readers
    - Arrangement of RFID Readers



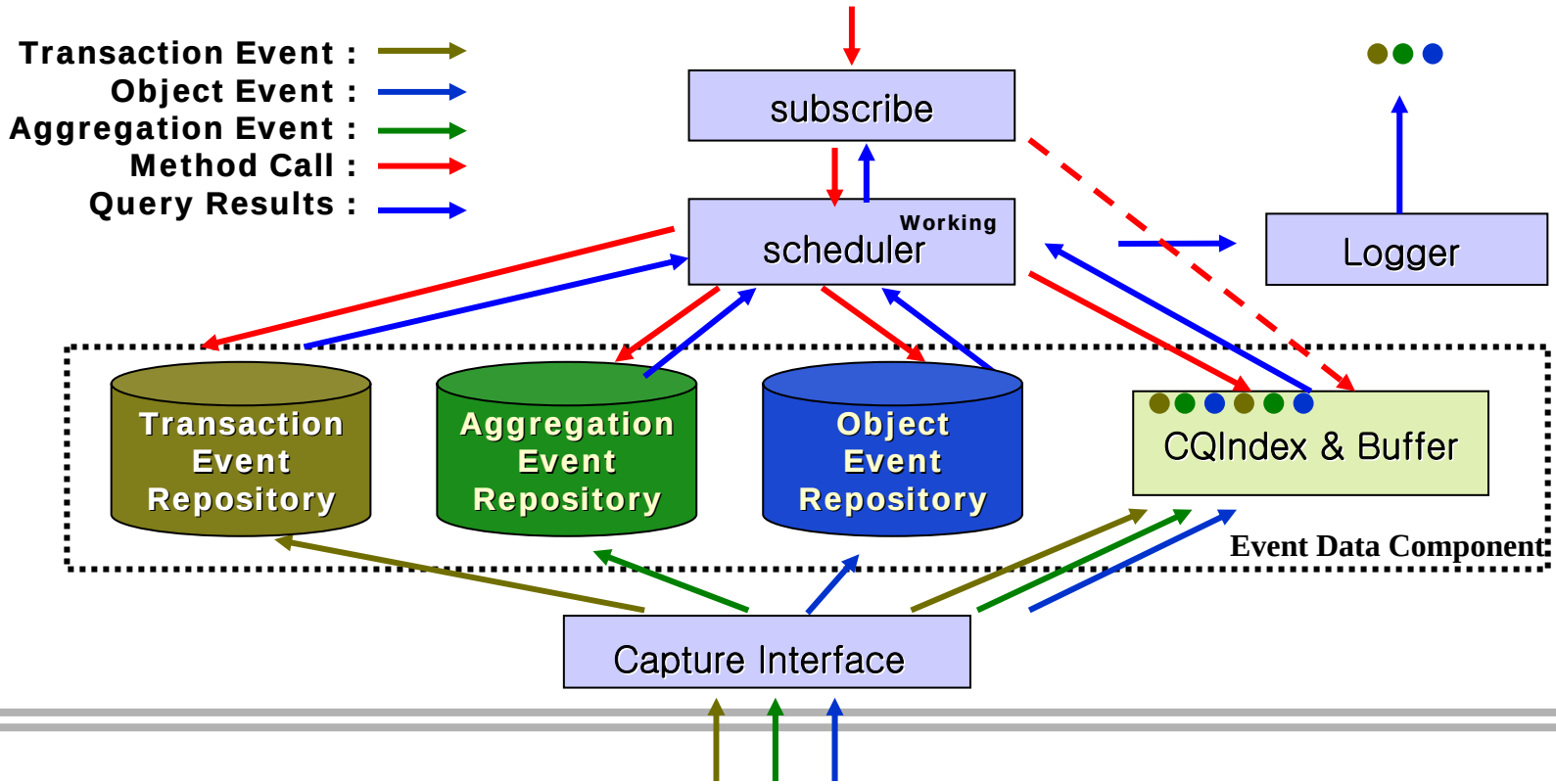
Features of ALE Manager

- **Reader Extensibility**
  - To support different types of RFID Readers from various vendors
  - UNIX Device Driver, Jini architecture
  - Adaptor look-up table



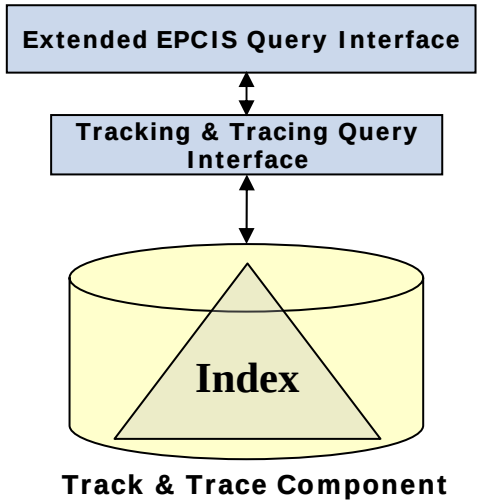
Features of EPCIS Manager

- ☑ **High performance and scalability**
  - ➢ Efficient Subscribe operation (using CQ Index technique)
    - Reduce processing time
    - Only first time access repository



Features of EPCIS Manager

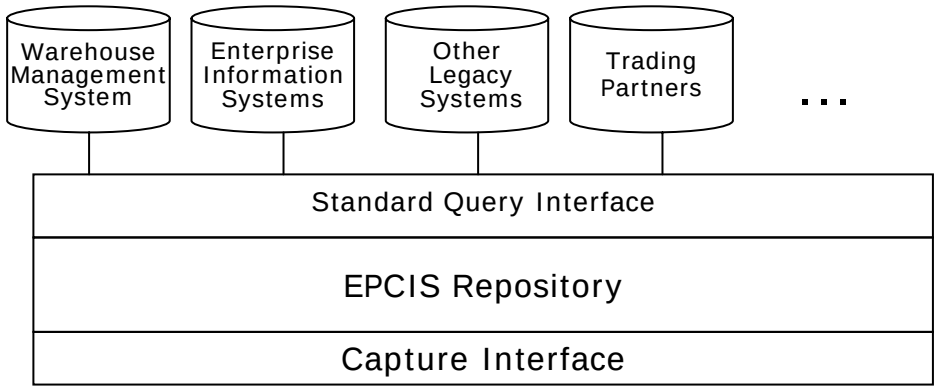
- ☑ **High performance**
  - ➢ Spatial index query for track & trace RFID tag object
  - ➢ Example of query
    - ● Where is the product #1? (present query)
    - ● Which products left warehouse B two hours ago? (past query)
  - ➢ Extended query interface
  - ➢ Fixed Interval R-tree*



*Design and Implementation of an Index Structure Using Fixed Intervals for Tracing of RFID Tags. *ICCSA, LNCS 3981, pp175-185*

Features of EPCIS Manager

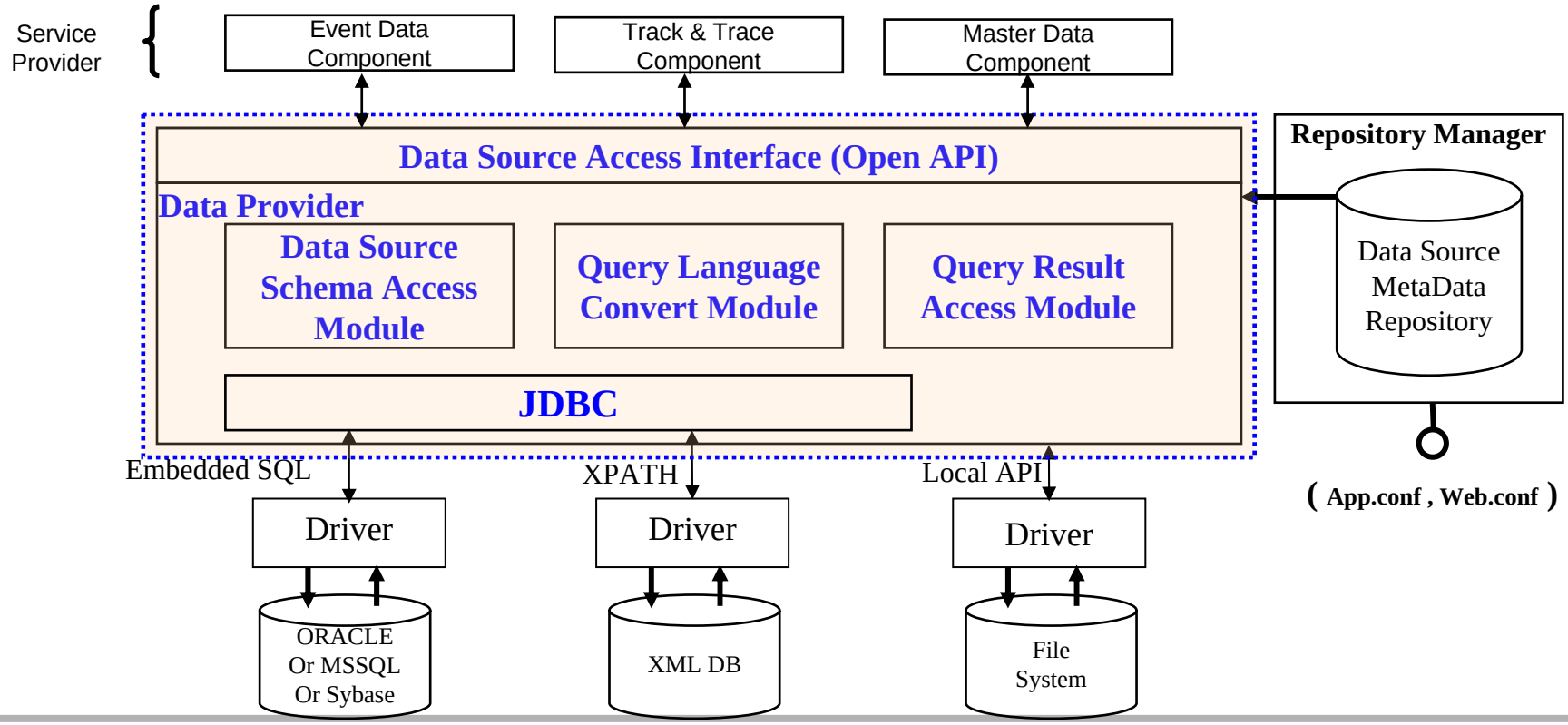
- ☑ **Application Abstraction**
  - ➢ Independent from types of applications
  - ➢ Persistent & compatible to store different types of EPCIS event.
  - ➢ Standard Query Interface (proposed by EPCglobal)
    - Standard data format
      - XML
    - Standard communication protocols : Query/Capture Service
      - HTTP
      - TCP
      - Web Service (wsdl)



Features of EPCIS Manager

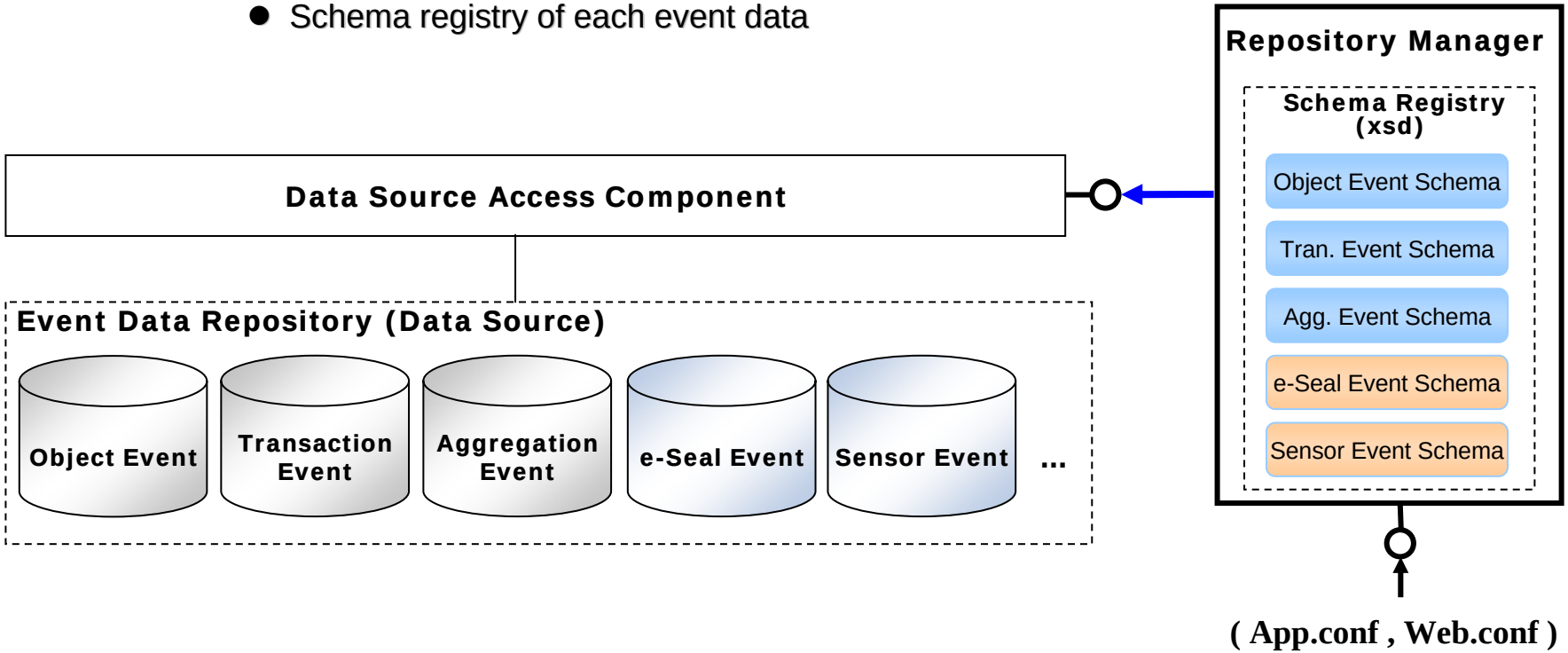
☑ Application Abstraction

- To support commercial legacy DB (Oracle, MSSQL…), XML DB and File system
  - We designed Data Source Access Component

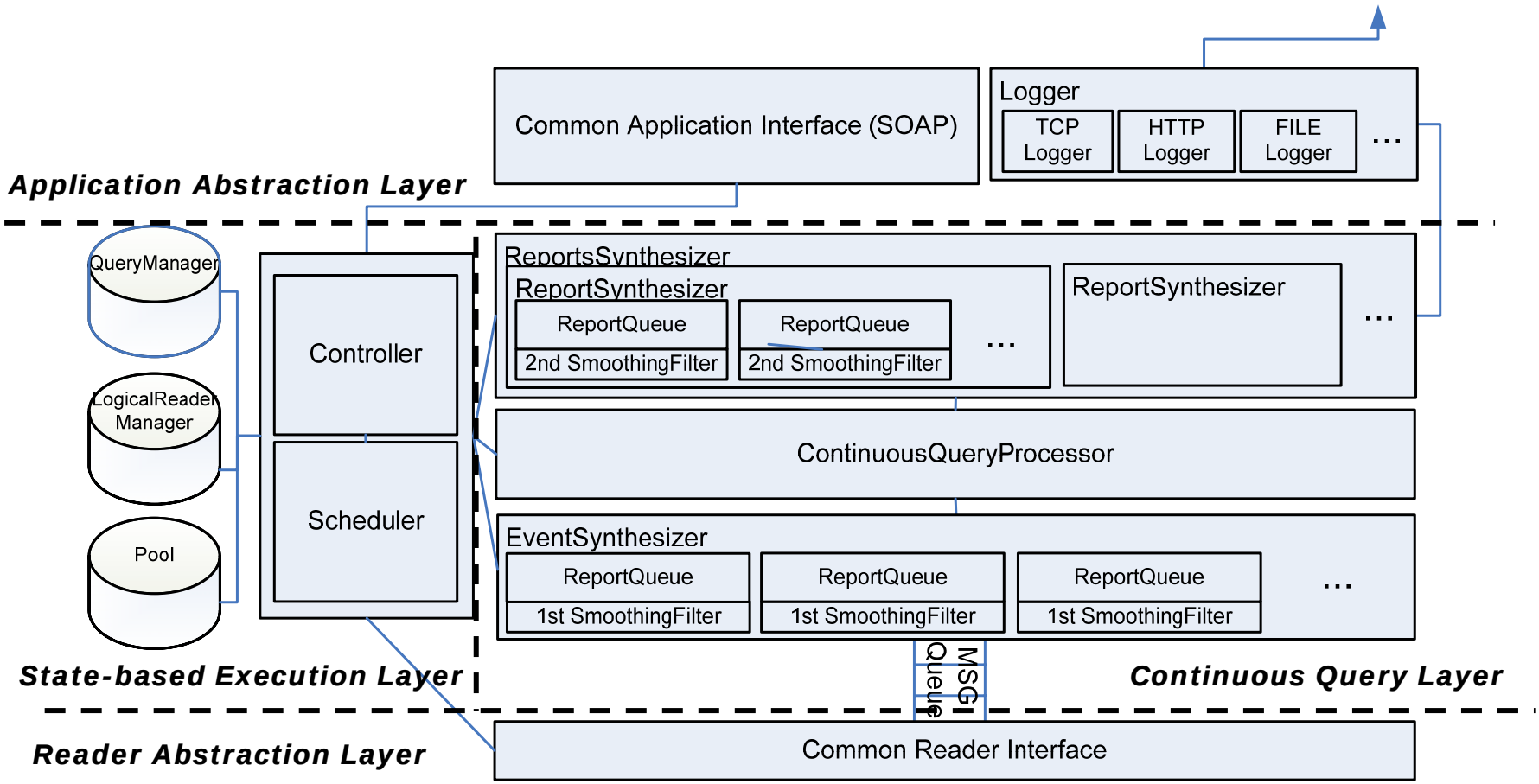


Features of EPCIS Manager

- ☑ **Extensibility**
  - To support new EPCIS Event
    - Ex: Sensor Event , e-Seal Event etc.
    - XSD, WSDL file extension.
  - Repository Management Module
    - Schema registry of each event data



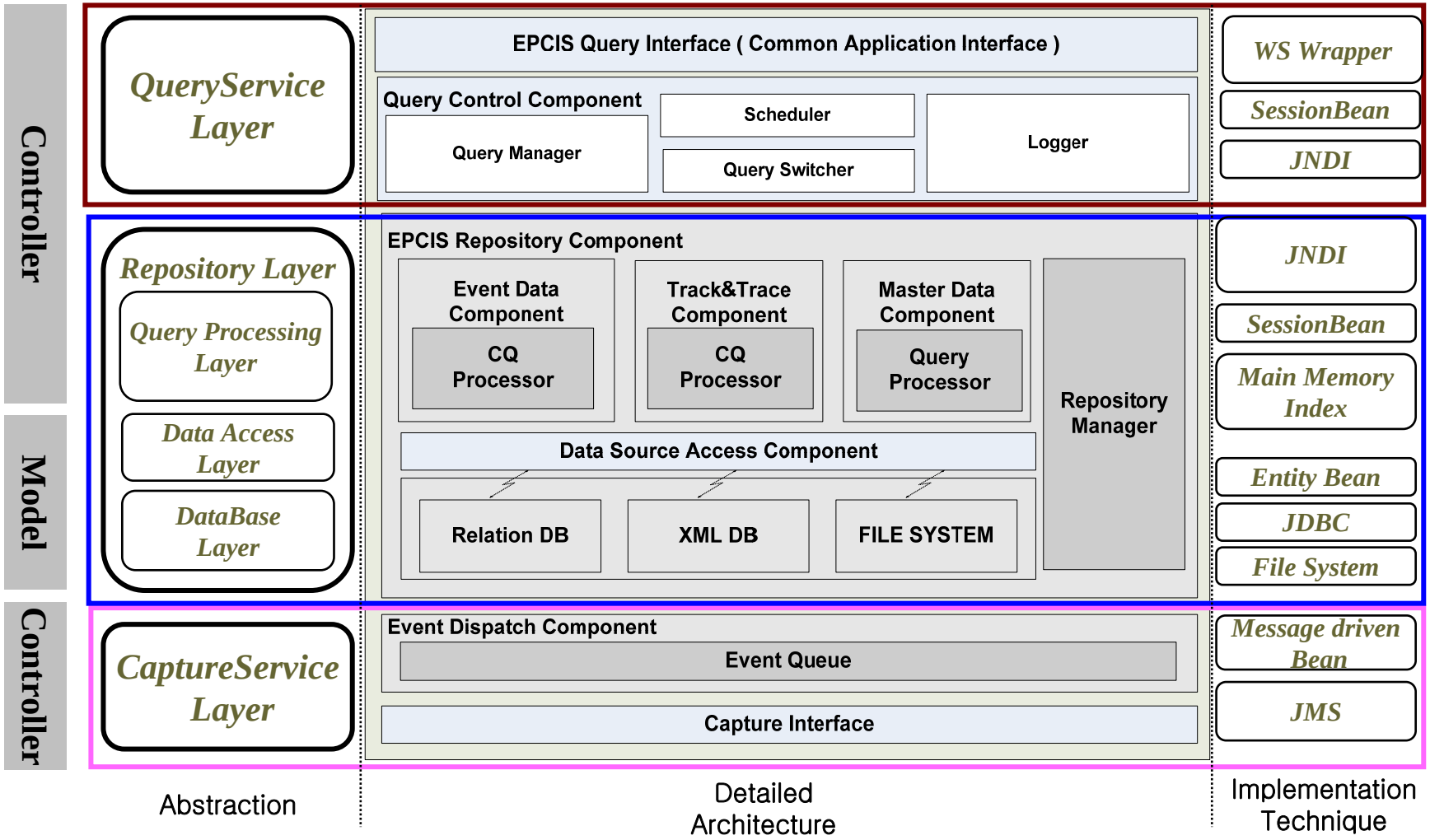
Software Architecture of ALE Manager



Software Architecture of ALE Manager

- **Reader Abstraction Layer**
  - Support different types of Readers from various vendors
  - Can integrate new Readers at runtime
- **State-based execution and Continuous Query Layer**
  - Control and manage ALE
  - CQ processor is implemented using query index
    - To support query defined by application
  - Query manager stores and manages query information
  - Reader manager keeps information of logical and physical reader mapping
  - Smoothing filter is used to remove duplicate data
- **Application Abstraction Layer**
  - Provides RFID data access by Standard Interface
  - Used standard protocol
    - TCP, HTTP, FTP, WSDL.
  - Support standard format (XML)

Software Architecture of EPCIS Manager



Software Architecture of EPCIS Manager

- **Capture Service Layer**
  - Provides standard interface
    - To capture events from EPCIS capturing application
  - Support standard format (XML)

- **Repository Layer**
  - Continuous Query processor for efficient subscribe operation
    - Implemented using query index
  - Implemented Fixed Interval R-tree for Track & Trace query
  - Implemented Data Source Access component
    - To support File system, Legacy DB and XML DB.

- **Query Service Layer**
  - Control and manage query processing
  - Provides Standard query interface
  - Used standard protocol
    - HTTP, WSDL

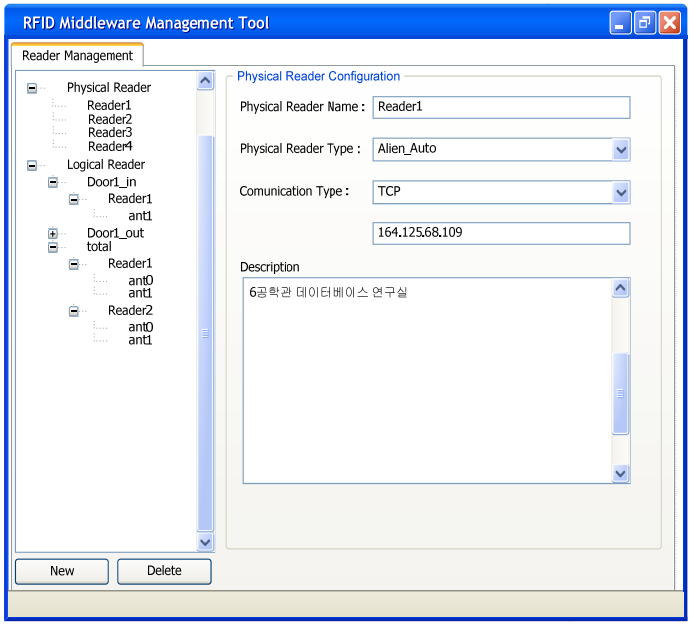
Implementation Environment

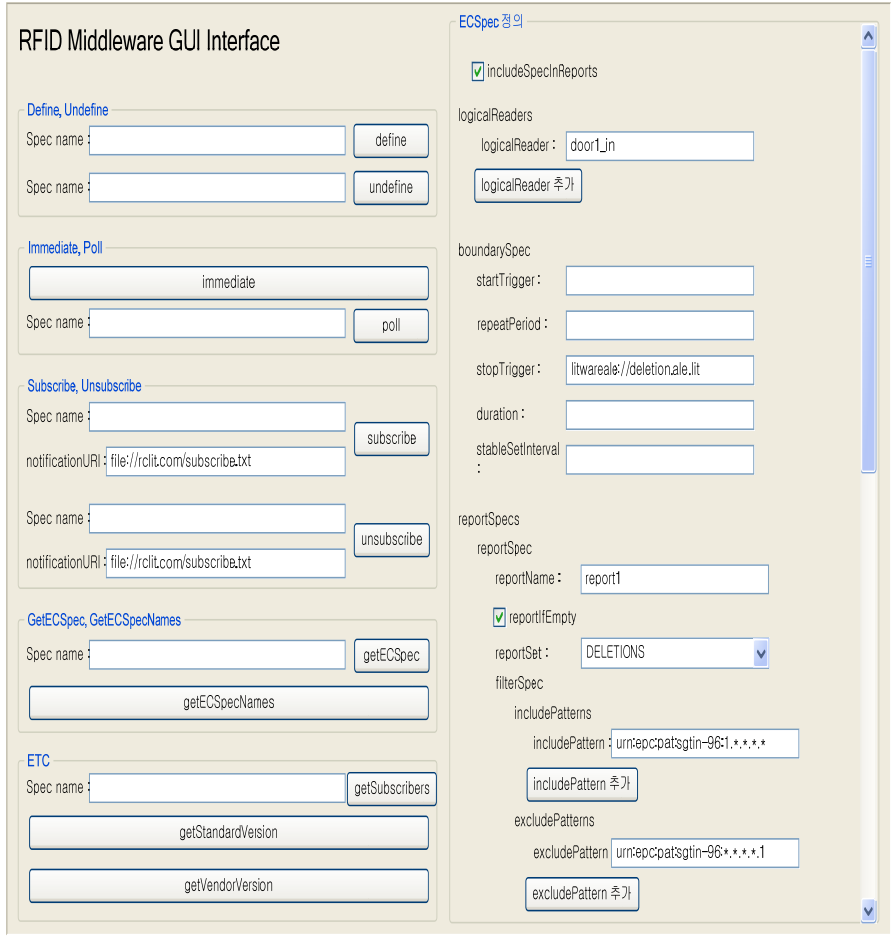
- **CPU:** Pentium IV 2.66 GHz.
- **RAM:** 1 GB.
- **OS:** Windows XP Pro. SP2
- **Language:** JAVA (JDK 5.0).
- **Web server:** SUN Application server.
- **RFID Reader, Antenna and Tag:**
  - Alien, Intermec, Kiscomm, KPC, LIT, Thingmagic.

Implementation

☑ Implemented software

- RFID middleware
- RFID Reader Management Tool
  - Manages physical RFID readers
  - Manages logical readers
- GUI for ALE Manager Client
  - Common Application Interface





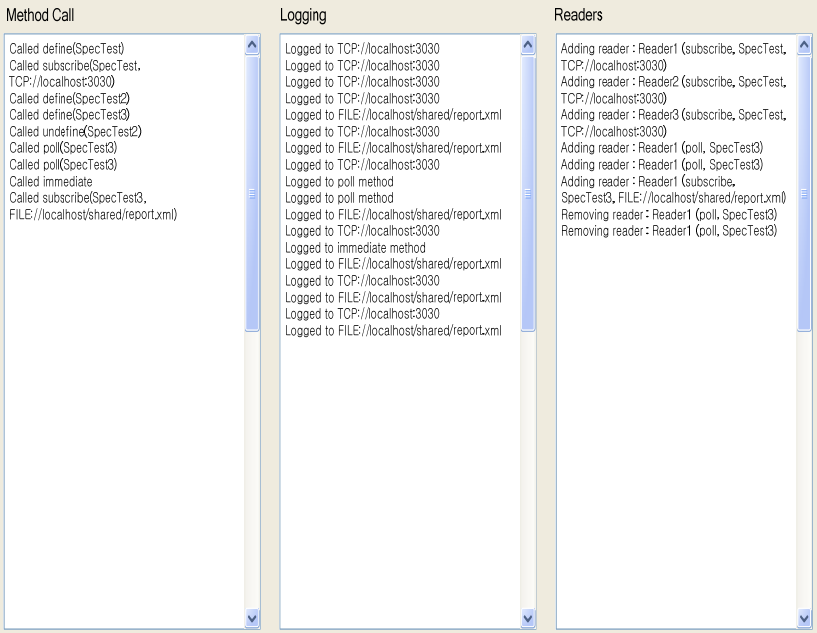
Implementation

☑ Implemented software

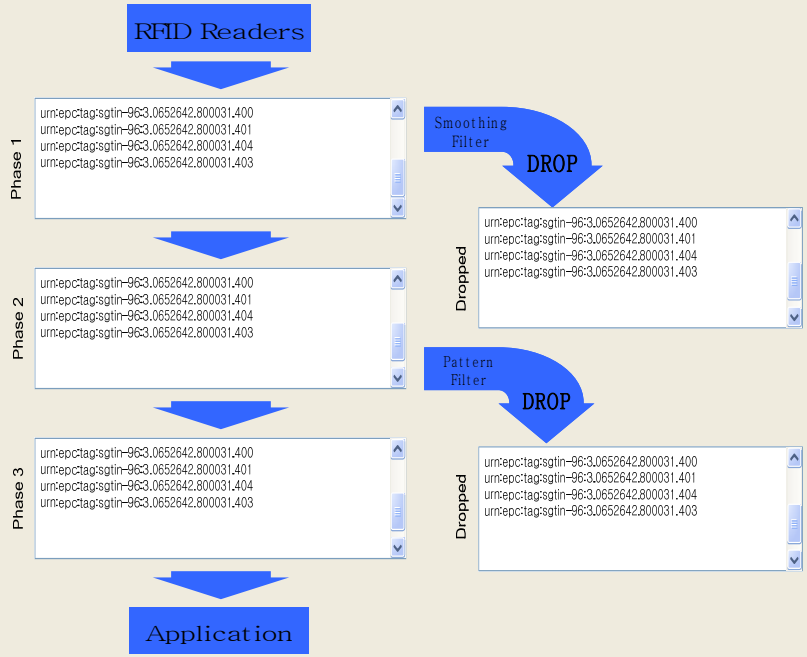
➢ RFID Middleware Monitor

- Monitor RFID tag data
- Monitor RFID middleware interface call

RFID Middleware Monitor - Interface



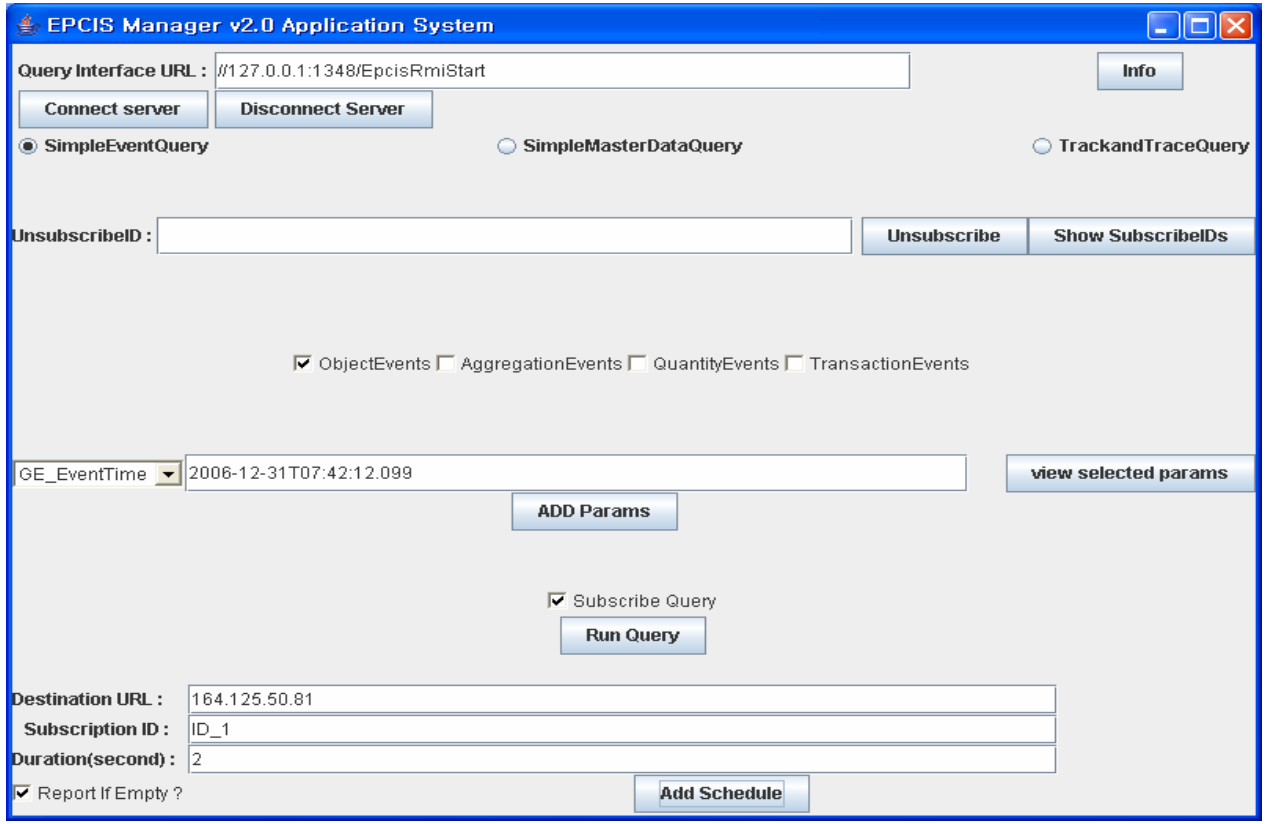
RFID Middleware Monitor - Tags



Implementation

☑ Implemented Software

- GUI for EPCIS Manager Client



Conclusion & Future work

☑ Conclusion

- Studied EPCglobal Network Architecture.
- Analyzed requirements of RFID Middleware
- Design Middleware based on EPCglobal standard
  - Layered Architecture
  - Provides important features such as High performance, Scalability, Abstraction and Extensibility
- Implement Middleware with features
  - User friendly GUI
  - Real time monitoring

☑ Future work

- Requirements analysis and implementation of Middleware to support
  - RFID, RTLS (Real Time Locating System) and Sensor data

Thanks for your attention

Questions?

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