White paper

RFID Software Interface Standards

Intermec®

This paper provides an overview of the more predominant RFID software interface standards either already existing or currently under development and expected to be ratified within the next two years. The Intermec Basic Reader Interface (BRI, which is a proprietary RFID interface) is also described and compared to the standard interfaces.

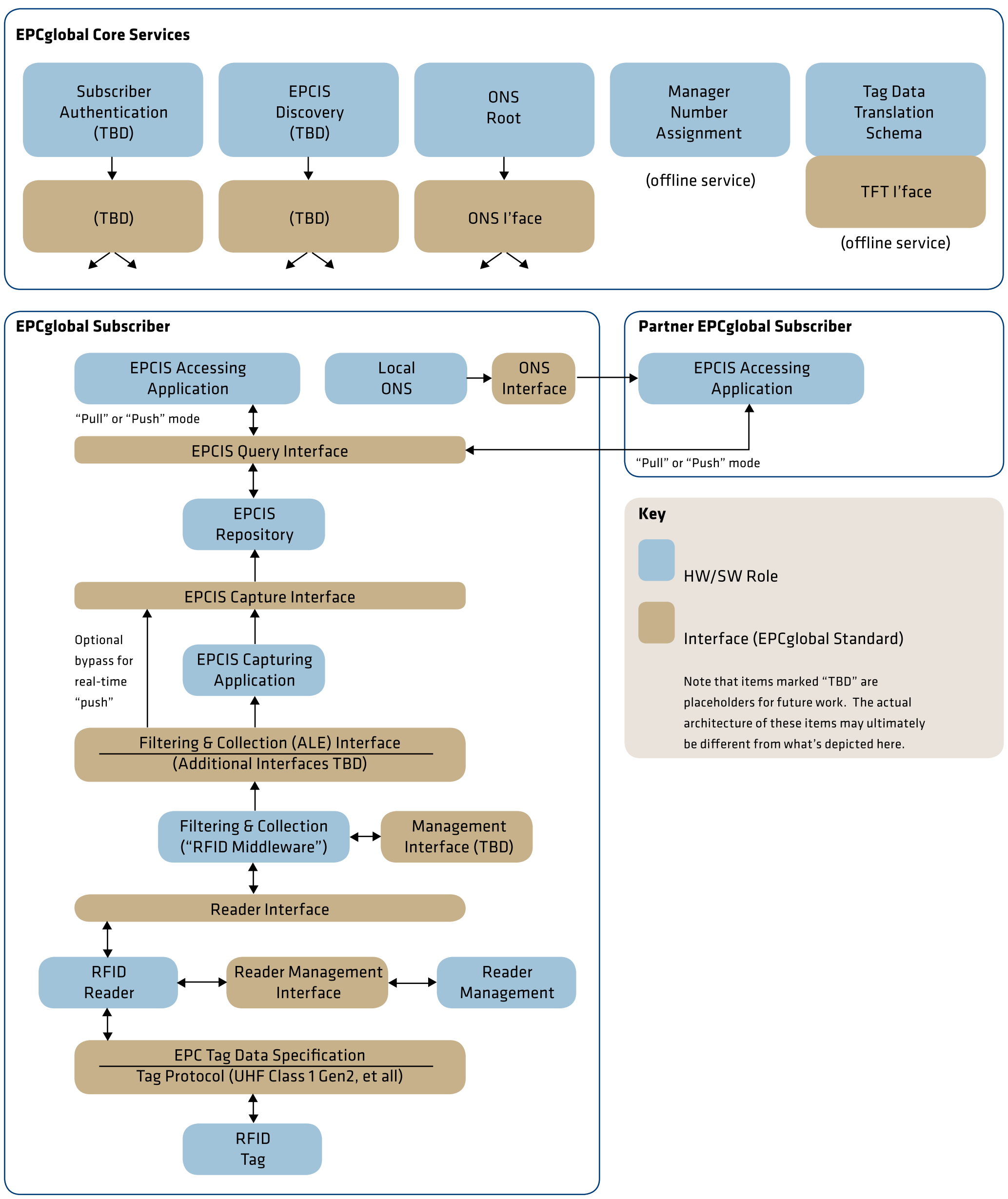
The description of RFID software standards is organized into sections, one for each organization pursuing RFID standards as follows:

- EPCglobal Inc.
- ISO SC31 / WG4 / SG1
- IATA Baggage Handling Group
- Other Standards Organizations
- Intermec Proprietary RFID Interface

EPCglobal, Inc.
EPCglobal has emerged as the RFID standards organization with the largest active membership. This is primarily due to the surge in interest for RFID by the consumer packaged goods (CPG) industry and the potential for ROI benefits when applying RFID to supply chain management (SCM). Other industries (e.g., airline transportation) are looking to other standards organizations (e.g., International Standards Organization [ISO]) in lieu of EPCglobal standards. However, RFID standards at other organizations are being heavily influenced by the RFID standards work forged by EPCglobal.

EPCglobal makes ratified standards available publicly at **www.epcglobalinc.org** "Standards" menu (top bar) | "Specifications" menu item. For other useful information regarding RFID, check out **www.epcglobalinc.org** | "Community" menu | "RFID Implementation Cookbook" menu item.

The EPCglobal Architecture Framework is documented and publicly available at **http://www.epcglobalinc.org/standards/Final-epcglobal-arch-20050701.pdf**. The diagram below is an excerpt from this document. It summarizes the framework. In this diagram, each brown-shaded box represents an EPCglobal software interface standard (currently ratified, under development, or planned for future development).



The current status of each EPCglobal standard is provided in the following table.

Interface Spec Name	Responsible Workgroup	Status	Comments
UHF Gen2 v1.0.9	HAG	Ratified	Air Protocol interface
UHF Gen2 next	HAG	TBD	Will address item-level tracking
TDS v1.3	SAG TDS	Ratified	
TDS next	SAG TDS	Awaiting requirements definition completion	Will address TID and User Memory
RM v1.0	SAG Reader Management	Ratified	Health monitoring only (SNMP MIB)
LLRP v1.0	SAG Reader Operations	Ratified	Strong reader vendor support
DCI v1.0	SAG Reader Operations	Ratification by December '07	Device management standard
HLRP	SAG Reader Operations	TBD	HLRP will be either RP v1.2 or it will go away. If HLRP goes away, then ALE v1.1 will take its role.
RP v1.1	SAG Reader Protocol	Ratified	Limited market acceptance.
ALE v1.0	SAG Filtering and Collections	Ratified	Strong middleware vendor support
ALE v1.1	SAG Filtering and Collections	Ratification by December '07	Strong middleware vendor support
EPCIS v1.0	SAG EPCIS Phase 2	Ratified	One standard defining two interfaces: Capture and Query.

The following paragraphs provide more description of each EPCglobal standard.

UHF Gen2
UHF Gen2 is an RF air protocol interface standard. It is passive RFID operating between 860-960 MHz. UHF Gen2 is having a huge impact on the adoption of RFID technology. This standard greatly improves RFID performance. The widespread adoption of Gen2 has significantly lowered the cost of RFID tags (< $0.20/tag).

Software developers using the LLRP interface will be required to understand some aspects of the UHF Gen2 specification.

Tag Data Standard (TDS)
The UHF Gen2 specification references the EPCglobal Tag Data Standard (TDS). In general, a Gen2 tag with bit 17_h of its EPC memory bank set to zero indicates that the tag is encoded according to the TDS. If this bit is set to one then the tag is encoded according to the ISO standards 15961/15962 (a later topic in this paper).

The following table defines the layout of the UHF Gen2 memory bank called the "EPC memory bank". Note that there is a data field within this memory bank that is also called the "EPC".

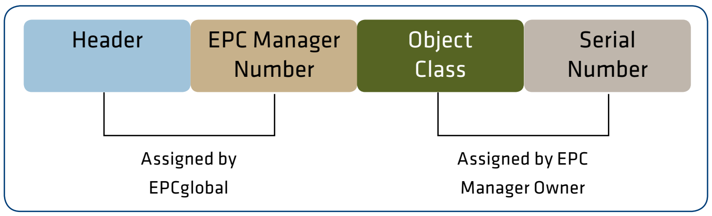
EPC Memory Bank Bit Offset	Description
00h-0Fh	CRC-16
10h-1Fh	Protocol-control (PC) bits
20h-xxh	EPC (electronic product code) variable length field
10h-14h	PC+EPC length (num words [16-bit] – 1)
15h-16h	Reserved (must = 0)
17h-1Fh	NSI (numbering system identifier)
17h	EPCglobal / ISO Indicator (17h = 0 → EPCglobal)
18h-1Fh	Reserved (must = 0)

Some RFID solution developers that are only deploying *closed-loop systems* (i.e., the RFID tags always move within the control of a single company), are ignoring the TDS. Instead, they are using their proprietary numbering schemes to encode RFID tags.

Nevertheless, systems that share RFID tags between companies should be based on an internationally accepted standard such as the EPCglobal TDS or ISO 15961/15962.

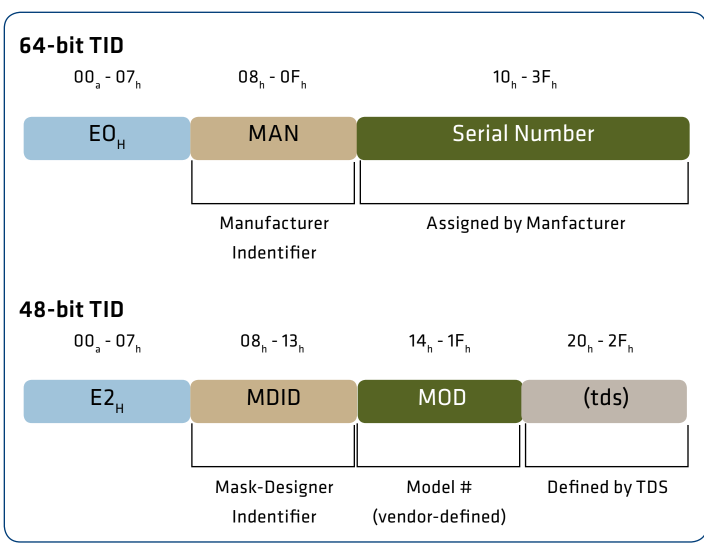
In general, it is advisable to adhere to a tag data standard even for closed-loop systems. ISO 15961-3 (currently only a draft) defines tag encoding rules specifically for closed-loop solutions (see ISO below). Using a tag data standard will help future-proof an RFID system and it will help avoid chaos that could occur should unmanaged, close-loop tags find their way into the proximity of supply chain processes (e.g., the unmanaged, closed-loop tags may be misinterpreted as being valid supply chain tags and convey incorrect information).

One draw-back to using the TDS is that, to insure that every tag is uniquely coded, tag values must be managed by a registration process and there's a fee associated with this process. Gen2 tags are uniquely coded by their EPC (electronic product code) which is formatted as illustrated by the following diagram.



Any company that creates Gen2 tags, in accordance with the EPCglobal TDS, must register with EPCglobal for a *manager number*. Once registered, a company becomes a *management entity* that is then responsible for the object class and serial numbers of the tags they create.

A new version of TDS is expected later this year. It will tackle standardization of both the Gen2 user and TID memory banks. The Gen2 specification does currently address TID memory bank encoding standardization (UHF Gen2 v1.1.0 section 6.3.2.1.3 TID Memory) but in a limited way. The following diagrams illustrate the requirements for TID memory.



Reader Management (RM)

The ratified RM specification defines a capability for monitoring the health of an RFID reader. This spec defines a reader in terms of an object model and various counters associated with the model. Reader statistics can be reported either via an XML/HTTP binding or via SNMP. The SNMP binding is specified as an SNMP MIB.

The RM workgroup continues to debug and update the SNMP MIB. Wal*Mart is using this MIB to manage the rollout of RFID readers within their organization. However, the RM workgroup is not expected to advance reader management beyond health monitoring. Instead, the Reader Operations workgroup is picking up where RM left off.

Note: there's been some confusion regarding RM and its relationship to RP v1.1. RM and RP share the same object module. And, RM's XML/HTTP binding is based on RP. While the two standards (RM and RP) were co-developed, they are not co-dependent. RM can standalone as a spec independent from RP and this is just how Wal*Mart is using RM today.

Low Level Reader Protocol (LLRP)

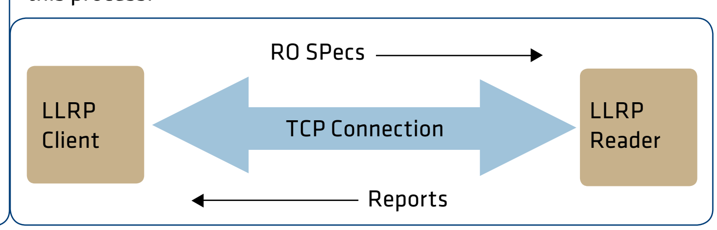
LLRP is expected to be ratified by late April '07. LLRP came about when it was discovered that neither RP nor ALE provided middleware providers with access to enough Gen2 air protocol details as is needed to implement optimized RFID solutions. LLRP therefore provides fine-grain control of the Gen2 air protocol and it provides access to Gen2 air protocol command parameters.

As an example of *fine-grain control*: with the LLRP interface, software can manage the start and stop of reader operations rather precisely (e.g., sub-millisecond if supported by the reader hardware). Examples of air protocol command parameters include such things as the *lock command payload* and the *select command action code*.

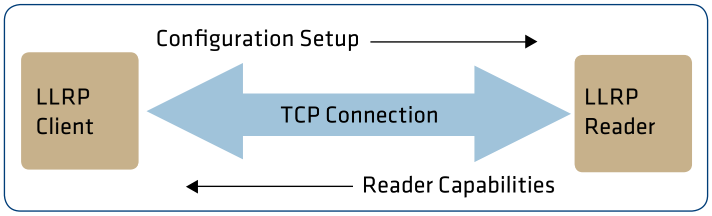
LLRP is intended for sophisticated RFID programmers that have a working knowledge of the UHF Gen2 specification. LLRP should be used to fine-tune an RFID solution to optimize RFID performance for a particular application of RFID. LLRP is not recommended for use by application programmers that simply want to read and write tags. For these users, a higher level interface such as ALE or Intermec's BRI is recommended.

The LLRP interface is a binary protocol designed to operate primarily over TCP. A serial transport is expected to be specified in LLRP v1.1.

Like ALE, LLRP is primarily declarative rather than imperative. This is to say that a device based on the LLRP interface can be set up to collect data autonomously. The following diagram illustrates this process.



LLRP restricts readers to accepting a single TCP connection. This one connection is used to send commands from the client to the reader and for the reader to return command responses and to send reports back to the client. In addition to sending reader operation specifications (RO Specs) to the reader, an LLRP client can command the reader to discover its capabilities and to set up configuration values in the reader (illustrated below).



Discovery, Configuration, and Initialization (DCI)
The RM workgroup took approximately three years to develop the RM spec. Due to this slow pace, when the Reader Operations workgroup was formed, the RO charter included a provision to pick up RFID device management where RM left off. Subsequently, the RO workgroup has drafted the DCI specification. It's not expected to be ratified until late 2007. As it stands today, DCI will be based upon the IETF draft standard CAPWAP (Control and Provisioning of Wireless Access Points) with the following contingencies:

- CAPWAP becomes an IETF standard.
- Cisco provides an open source reference implementation of CAPWAP (both Reader and server end-points).
- The DCI spec can extend CAPWAP to enable bi-directional connection initiation.

The primary Reader device management features to be addressed by DCI are:

- Discovery. Either Readers discovering DCI Servers or DCI Servers discovering Readers.
- Authentication. Either one-way or two-way authentication. Readers authenticating DCI Servers and DCI Servers authenticating Readers. This feature may be optional and not used where environments are considered to be secure by physical constraints or other means.
- Configuration Settings. DCI Servers reading and writing configuration settings on Readers. This will be a minimal set of configuration elements required to put a Reader into a state where it is capable of performing other reader operations (e.g., LLRP or ALE).
- Firmware upgrade. DCI Servers will be able to update firmware on Readers.

High Level Reader Protocol (HLRP)
HLRP is a place-holder that is being used to determine the fate of RP. There is quite of bit of overlap between RP v1.1 and ALE v1.1. Some people don't believe it's necessary to have both RP and ALE due to this overlap. If the decision is made to keep RP, then HLRP will become the next version of RP v1.1. If a decision is made to adopt ALE in place of RP, then HLRP will be dropped.

In either case, ALE will continue to evolve under the direction of the Filtering and Collections workgroup.

Reader Protocol (RP)
RP is a high-level reader protocol. Unlike LLRP, RP abstracts and hides reader implementation details from programmers. RP is therefore easier for application programmers to use. However, as mentioned above for HLRP, functionally there's quite a bit of overlap between RP and ALE.

Aside from the overlap with ALE, one problem with RP is that it attempts to satisfy a wide audience and as such it's not a very definitive standard. For instance, approximately 80% of the RP's specified features are optional. RP defines both XML and plain-text interfaces. It also defines serial, TCP, and HTTP transports. There are other minor problems with RP that Intermec attempted to rectify during the development of RP but to no avail.

Due to the wide-spread adoption of ALE and limited adoption of RP, it is expected that RP will eventually lose market support.

Application Level Events (ALE)
Application level events represent observations that are reported without any business context associated with them. These observations are abstracted to include not only RFID reads, but bar-code scans and manual data entry.

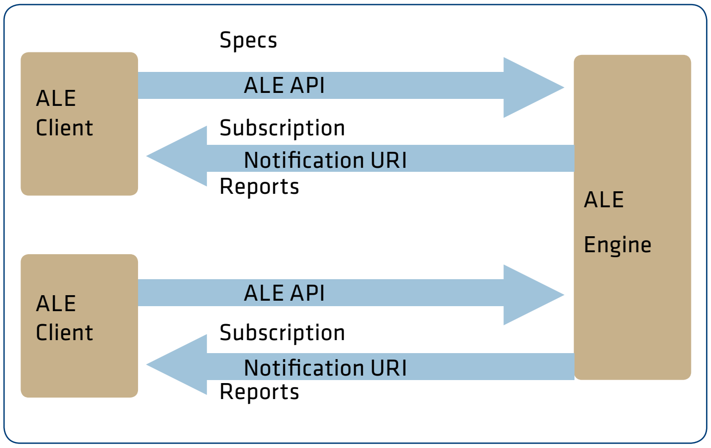
The ALE interfaces were devised to enable a data collection mechanism that can operate autonomously reading and reporting RFID observations. An ALE implementation is intended more to be configured than to be programmed. The ALE data collection mechanism hides low-level hardware details (e.g., barcode, RFID, sensors, etc.). It manages data filtering and aggregation of input from multiple devices.

ALE is a high-level reader protocol with features that overlap with RP. For more detail on the relationship between ALE and RP, see the discussions above for HLRP and RP.

A system component that implements the ALE interface is called an "ALE engine". The intent is that an "ALE engine" reports only observations (i.e., there's no attempt to associate business context with the observations).

The ALE interface is primarily declarative versus imperative (imperative is also known as command/response). That is to say, host software interacts with an ALE engine by sending data collection specifications (e.g., when to read, what to filter, where to report results, etc.). The ALE engine then operates autonomously to execute its data collection specifications. You can think of an ALE engine as a data collection engine. You give the engine specifications as to when and what data want to collect. Once configured, the ALE engine will autonomously collect data as it is observed. Any ALE client can subscribe to the ALE engine to automatically receive reports on data collected. ALE uses the term Notification URI to designate the communications path used to report collected data.

The following diagram illustrates the interaction between ALE clients and an ALE engine.



The ALE interfaces are based on XML. An ALE engine is configured using XML documents called specs (e.g., ECSpec, CCSpec, …). Specs are communicated from an ALE client to an ALE engine via a web services interface called the ALE API (WS-i compliant). An ALE engine communicates its reports as XML documents. These reports can be communicated via files, HTTP, or other vendor-specific mechanisms such as message-oriented middleware (e.g., MQ Series).

EPC Information (EPCIS)

In some ways, EPCIS competes with existing business-to-business data exchange standards such as EDI. EPCglobal leadership initiated the development of the EPCIS standard due to perceived weaknesses in the existing B2B standards. For instance, EPCIS supports queries (a pull model) and EDI is based on a push model. It is expected that RFID will greatly increase the amount of data exchanged between business and that the existing data exchange standards won't adequately scale to meet the data volume increase.

It should be noted that EDI has evolved. Wal*Mart has promoted EDI over Internet (EDI-INT) based on the communication standard AS2. For more information see: **http://www.e-future.ca/sask/pdf/b2b_basics.pdf.** Nevertheless, Wal*Mart and other retailers have participated in the development of EPCIS.

EPCIS Phase 2 is a single specification defining two interfaces: 1) Data Capture and 2) Repository Query.

The EPCIS Capture Interface produces events that correlate tag observations and business context. Events are correlated to business context usually by references to master data which can represent various aspects of business (e.g., locations, business process steps, or business transactions).

EPCIS Capture Events are stored persistently in the EPCIS Repository (e.g., a commercial database configured to support EPCIS). The EPCIS Query Interface provides access to the data in the EPCIS Repository. The query interface supports both intra-company data access but also business-to-business access.

ISO SC 31 / WG 4 / SG 1

ISO SC 31 (International Standards Organization, sub-committee 31) was writing RFID standards long before EPCglobal. However, ISO has not profited from the large member participation that EPCglobal has enjoyed more recently. Consequently, ISO has not produced the large set of RFID software standards such as those coming from EPCglobal.

By policy, ISO standards are not public. ISO standards must be purchased. ISO SG 1 working documents are archived at: **http://www.autoid.org/SC31/sc_31_wg4_sg1.htm .**

ISO SC 31 / WG 4 / SG 1 is responsible for software-related standards. ISO SC 31 has produced the 18000-6C specification which is the ISO equivalent of the EPCglobal UHF Gen2 air interface spec. 18000-6C is, for the most part, simply and *ISOized* version of the EPCglobal spec which is largely only a change in formatting and clause numbering. ISO did change the EPCglobal terminology slightly. For instance, the term EPC (electronic product code) was changed to UII (unique item identifier).

The following table defines the layout of the 18000-6C memory bank called the "UII memory bank". Note that there is a data field within this memory bank that is also called the "UII".

UII Memory Bank Bit Offset	Description
00_h-$0F_h$	CRC-16
10_h-$1F_h$	Protocol-control (PC) bits
20_h-xx_h	UII (electronic product code) variable length field
10_h-14_h	PC+UII length (num words [16-bit] – 1)
15_h-16_h	Reserved (must = 0)
17_h-$1F_h$	NSI (numbering system identifier)
17_h	EPCglobal / ISO Indicator bit (17_h = 1 → ISO)
18_h-$1F_h$	AFI (application family identifier)

AFI codes are specified in ISO 15961 Annex B. For closed-loop applications it is recommended that users consult ISO 15961-3 clause 4 (currently only a draft standard) which defines AFI values 1-3 specifically for closed-loop applications. This then will indicate to any ISO-compliant middleware that the coding on the tag can only be interpreted by a custom application designed specifically for this tag. Of course, if a closed-loop application tag falls into the proximity of a different closed-loop application, then the tag will be incorrectly interpreted. This is the danger of using closed-loop numbering schemes on RFID tags.

ISO SC 31 has produced other air interface specs including 18000-3 (13.56 MHz) 18000-6A, and 18000-6B. Intermec has products supporting 18000-6A/B. However, this technology is out-dated. It's much lower performance, and the tags are considerably more expensive than UHF Gen2. Intermec will continue to support customers with legacy 18000-6A/B systems.

In 2004 ISO released two co-dependent standards 15961 and 15962. These specs are complicated and difficult to understand. One problem is that the specs are a mixture of a tag data standard, a reader interface standard, and a reader design. Intermec is currently working actively with ISO SG 1 to have 15961 deprecated and to re-write 15962 as a tag data standard only.

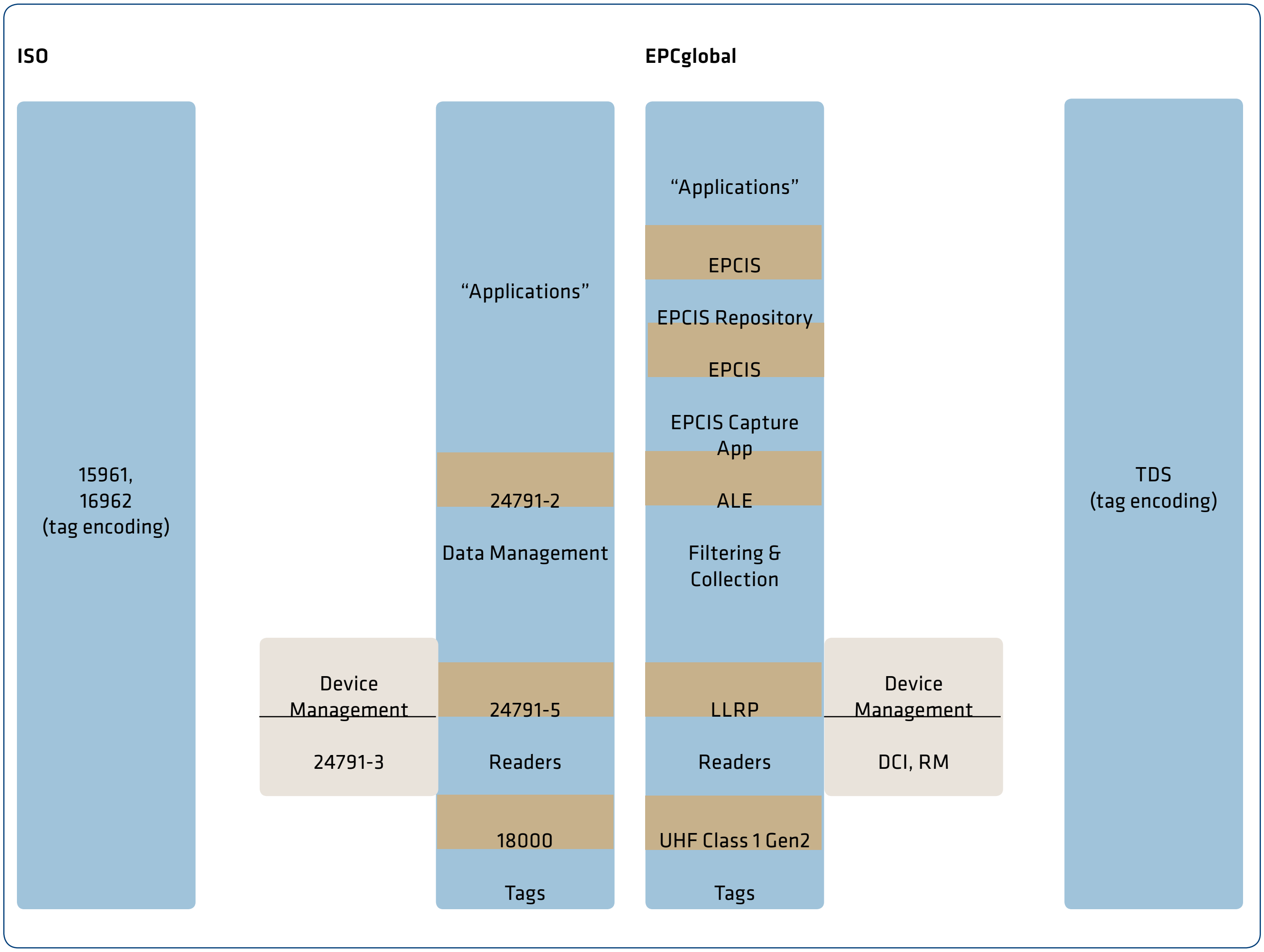
The reader interface defined by 15961/15962 has a number of flaws. Foremost, this interface is incomplete. It includes no provisions for reader setup or the ability to optimize reader performance for a particular application. It does not include specific support for 18000-6C tags. Another problem is that the reader interface is defined in terms of ASN.1/BER transfer encoding which is an old, complicated and currently unpopular encoding scheme.

ISO SG 1 is currently developing a new standard, 24791, that will define RFID software systems interfaces. 24791 will be composed of 6 parts:

1. Overview. ISO RFID Software System Infrastructure.
2. Data Management Interface. A high-level reader interface for RFID.
3. Device Management. This part will attempt to address all aspects of RFID device management including –
    a. Device discovery
    b. Software provisioning
    c. Configuration setup
    d. Health monitoring
4. Application Interface. This is a place holder and its status is TBD.
5. Device Interface. A low-level reader interface for RFID.
6. Security. Software interface security requirements.

This standard isn't expected to be ratified until Q1'08.

The ISO community recognizes the disparity between EPCglobal membership participation and the minimal participation at ISO. Consequently, last year ISO SG 1 decided to start adopting EPCglobal software standards rather than duplicating this work. The following diagram illustrates the mapping between ISO standards and EPCglobal standards.



IATA
IATA's (International Air Transport Association) Baggage Workgroup has approved RP 1740C, a recommended practices standard for airlines using RFID to track baggage. This standard references ISO 15961/15962 and this has caused a great deal of confusion because 15961/15962 define both a reader interface and a tag data standard. No one implements the reader interface defined in these standards (see ISO discussion above). Nevertheless, airlines have begun to require RP 1740C compliance. For the most part, the reader interface aspect of 15961/15962 has been ignored and RP 1740C compliance has been considered to only require ISO tag data compliance.

Intermec has visited the IATA Baggage Workgroup and presented the work that ISO is doing to define RFID software systems interfaces in 24791. Intermec has also contacted airlines directly to help educate the airline community about the on-going development of ISO standards.

Other Standards Organizations

ANSI
ANSI/NCITS T6 256-2001 defined a "C" language API for the purpose of interfacing to readers. Intermec had support for this API until around 2005 when the "T6 API" was deprecated and replaced with Intermec's Basic Reader Interface.

Near Field Communications
You may come across NFC standards for RFID such as RFID built into cell phones. NFC standards are also applicable to smartcards. This RFID technology is very short range. Intermec currently has no investment in NFC because it's not a requirement for the automated data collection markets we serve. See **www.nfc-forum.org** or **www.nearfield.org** for more information regarding NFC.

IETF
The International Engineering Task Force is the standards organization responsible for most of the internet standards we're all familiar with (e.g., FTP, HTTP, NTP, SNMP, NFS, …). These networking standards are relevant to Intermec RFID fixed readers. Most recently IETF standard capabilities have been added to the IF61 to enable it as an Ethernet plug-and-play device. IETF RFC 3927 (LLA) allows the IF61 to achieve local-subnet connectivity by automatically assigning itself an IP address. The IETF draft standard, MDNS (**http://files.multicastdns.org/draft-cheshire-dnsext-multicastdns.txt**), will become an IETF RFC later this year. MDNS is built into the IF61 and it allows you to automatically discover an IF61 on the local-subnet from your IE browser.

UPnP Forum
See **www.upnp.org** for information about the UPnP forum and its standards. This standard was promoted principally by Microsoft. Something like the IETF MDNS, the IF61 also incorporates UPnP standard support to help facilitate IF61 discovery from a Windows environment. With UPnP support, the IF61 is automatically discovered by Windows and displayed in Windows File Explorer's "My Networks" tree.

OASIS
IBM has worked within OASIS to create a standard called Web Services Distributed Management (WSDM).

See **www.oasis-open.org/committees/tc_home.php?wg_abbrev=wsdm.**

IBM has built IT management capabilities into the provisioning component of Tivoli. We have had conversations with IBM about adapting WSDM for RFID. Most importantly, we would like to standardize a firmware upgrade interface to our readers via WSDM. Secondly, we're exploring the possibility of adding Intermec's Observation Framework (OF) support to the WSDM Metrics framework.

This initiative has a lot of potential benefits for Intermec; however it's been difficult getting IBM engaged to support this work. Meanwhile, there's a competing standard, WS-Management (see below).

DMTF
The Distributed Management Task Force is spear-heading much of the most recent developments in IT management standards. In particular, the DMTF is expected to ratify Web Services Management (WS-Management) by May '07.

There appears to be a large adoption for WS-Man. Principle contributors include: Microsoft, HP, Dell, Intel, Oracle, Sun, and BEA.

The Microsoft RFID middleware team is working on integrating RFID device management into their software infrastructure. WS-Management is being considered for this initiative. Firmware upgrade will be the first priority. Diagnostic capabilities such as provided by OF are also being considered. Intermec is working closely with Microsoft to promote standards-based RFID device management.

In addition to Microsoft, Intermec is also working with HP and BEA who are RFID partners that plan to build WS-Management capabilities into their IT management products. We have RFID sales activity that includes HP C&I. One thing we're doing is attempting to get the HP C&I folks in contact with HP IT management products group. It's the IT management folks that are building WS-Management capabilities into HP products such as OpenView. We're working to see whether OpenView can be enabled to manage Intermec RFID devices via standard interfaces.

Intermec Proprietary Reader Interface
Intermec's proprietary reader interface is the Basic Reader Interface (BRI). BRI offers some advantages that none of the emerging standard interfaces provide. The following list enumerate the advantages of BRI.

Advantages:

- Intuitive, command-line interface (CLI) approach. Low learning curve.
- Human-readable (ASCII text). It's a scripting language that enables rapid-prototyping.
- TCP interface. Easily accessible via Telnet.
- OS and programming language independent.
- SQL-like programming model. Familiar to many programmers.

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