The current issue and full text archive of this journal is available at
www.emeraldinsight.com/0264-0473.htm

Received 4 October 2013
Revised 16 February 2014
6 May 2014
6 June 2014
12 June 2014
Accepted 13 June 2014

A study of UHF-RFID data model construction in university libraries

Jing Guo
System Support Department, Shanghai Jiao Tong University Library, Shanghai, China
Qinling Huang
Reader Service Department, Shanghai Jiao Tong University Library, Shanghai, China; and
Jiayi Chen
System Support Department, Shanghai Jiao Tong University Library, Shanghai, China

Abstract

Purpose – The purpose of this paper is to put forward a Ultra-high Frequency Radio Frequency Identification (UHF-RFID) data model construction scheme for university libraries, hoping to realize the opening, uniform, compatible and interoperable RFID application between different libraries and manufacturers.

Design/methodology/approach – This article uses the practical application needs of university libraries as the starting point, and proposes the UHF-RFID data model construction scheme for university libraries based on the study of applicable standards, such as ISO 28560.

Findings – Based on practical application demand of university libraries and some international standards, the paper puts forward an UHF-RFID data model construction scheme for university libraries. First, the scheme explains and defines six user data elements different from ISO28560: version, owner library identifiers, temporary item location, subject, International Standard Serial Number (ISSN) and International Standard Book Number (ISBN). Furthermore, different encoding rules for electronic product code (EPC) data area and user data area are designed to achieve maximum work efficiency.

Practical implications – This paper tries to bring forward a set of referential UHF-RFID data model standards for university libraries. Hopefully, this standard will offer uniform data models for university libraries to comply with, integrate the disordered market and further make the opening, unified, compatible and interoperable RFID application possible.

The authors would like to express sincere gratitude to Shanghai Jiao Tong University fund and the Chinese Fund for the Humanities and Social Sciences because this research is supported by the Research Project of Shanghai Jiao Tong University Fund for Social Sciences & Natural Sciences: Research on Smart Library Service based on Innovative RFID Technology (Grant No. 11JCY07) and Key Research Project of Chinese Fund for the Humanities and Social Sciences: Research on Information Resource Integration and Service under the Environment of Cloud Computing (Grant No. 12 & ZD220). Many thanks go to the RFID Technology Application Union for University Libraries who have made this research possible. Moreover, we would like to express our cordial thanks to the editors, reviewers and colleagues who have given many valuable suggestions to the paper.

The Electronic Library
Vol. 32 No. 5, 2014
pp. 726-741

0264-0473
DOI 10.1108/EL-10-2013-0177

Originality/value – Although there are several formally published RFID standard documents, they are primarily designed for high frequency RFID technology. Concerning UHF-RFID technology, there are still no internationally unified data model standards. Hence, this paper brings forward the UHF-RFID data model construction scheme for university libraries.

Keywords Uibraries, Data model standards, Encoding schemes, ISO 28560, RFID application, UHF-RFID, Data models

Paper type Research paper

1. Introduction

Radio frequency identification (RFID) technology is a non-contact identification technology which can perform automatic target recognition through radio frequency signals by accessing relevant data. This technology is now widely used in civilian areas such as production automation, road tolls, parking management, logistics and so on. In the twenty-first century, RFID technology has widespread applications in libraries. Currently, in libraries, there are two normal RFID frequencies, high frequency (HF)-RFID (13.56 MHz) and ultra-high frequency (UHF)-RFID (860 MHz to 960 MHz). As UHF-RFID has several significant advantages over HF-RFID, such as longer reading distance, higher sensitivity, greater development potential and lower cost, with technological advances in recent years, UHF-RFID technology has gradually occupied the leading position in libraries.

As the RFID chip itself can store information data, libraries using RFID technology gradually realized the importance of standardizing the data stored in the RFID chips; thus, a number of RFID data model standards have been proposed. In 2011, with the formal and final version of the international standard ISO 28560-1 (2014), ISO 28560-2 (2014), ISO 28560-3 (2014) formulated and issued, different countries put forward library data model standards in line with this standard. In 2010, the National Library of China issued *RFID Library Draft for the Data Model* and submitted it to the Ministry of Culture of the People's Republic of China in 2012. Afterwards, the draft became a standard for the cultural field (WH/T 43-2012 and 44-2012, 2012).

Looking back through history, the Danish RFID library data model Danish Standards Foundation (DS/INF) 163, the earliest library RFID data model known to the public, was issued online. This model put forward data element names, sequence numbers for the tags and a scheme of tag marking which is an encoding program using the mixed model of fixed-length data and variable-length data. In September 2006, Australia made public their *Library RFID Data Model Proposal* which advanced the "content parameter" and "dynamic encoding" schemes. Additionally, Australia introduced the code system in the ONIX media format to the publication field, and set optional data elements and order. This proposal is the turning point that provided for non-fixed-length encoding schemes to be available in the library RFID data model proposals. In December 2007, the National Information Standards Organization released *RFID in American Libraries* (*Application Guide*), which showed its approval of the Australian "content parameter" and "dynamic encoding" schemes, and set free data elements and sequence. During 2003 and 2007, RFID standard organizations of Netherlandish, Finnish, French and German and English, issued their own library RFID application standards in succession. Under the influence of the Danish data model published earlier, a number of countries in the north of Europe, such as Netherland, Finland and France, all issued "fixed-length encoding" schemes similar to the Danish

model. Later, the standard organization of Australian libraries advanced the "dynamic encoding" scheme, which was approved by standard organizations of American and English libraries. Danish, Australian and American standards have become the most influential data model standards in the library field, which laid the foundation for the appearance of binary encoding schemes in the ISO 28560 standard. Eventually, the "dynamic encoding" and "fixed-length encoding" schemes of ISO 28560-2 and ISO 28560-3 were issued simultaneously. Different libraries can thereby choose encoding modes suitable for themselves according to their own needs (Chen *et al.*, 2005).

Although the ISO 28560 standard has been approved and is being obeyed by most countries, the three formally published standard documents are chiefly formulated for HF-RFID technology. Currently, as to UHF-RFID technology, there is still no fixed data model standard. In 2011, China's Guangdong province put forward the DB 44 RFID provincial standard of book management (DB 44/T 898.1-2011, 2011, DB 44/T 898.2-2011, 2011), which is mainly for UHF-RFID technology. Nevertheless, this standard is generally formulated by referring to ISO 28560 and does not embody or suit features of UHF-RFID. Additionally, it is not designed for university libraries. Because there are big differences between management models and application needs of university libraries and public libraries, there will be dissimilar views on the actual demand of data models. The present standard does not satisfy the application demand of UHF-RFID in university libraries. Under the circumstances, it became an urgent need for university libraries to establish an open and internationally compatible data model standard which supports large-scale circulation such as interlibrary loan (ILL).

2. Objectives and principles

Because the library UHF-RFID market is chaotic, incompatible, non-standard and devoid of unified data model standards, three university libraries in mainland China and Hong Kong (City University of Hong Kong, Shanghai Jiao Tong University and Tsinghua University) jointly launched and preliminarily reached an agreement to find the "RFID Technology Application Union for University Libraries" (hereinafter referred to as the "Union") and established a working committee for the Union in March 2010. Until the beginning of 2013, five working meetings were held and dozens of eminent university libraries in China were attracted to take part in it (Consortium for RFID Applications in Higher Education Libraries, 2013).

Entrusted by the Union, Shanghai Jiao Tong University library studied and designed a set of data model standards, aiming to provide a set of UHF-RFID data model standards suitable for and compatible with international standards for university libraries to employ UHF-RFID technology; ensuring that university libraries are able to use UHF-RFID technology according to their own needs. During the process of design, the following basic principles were considered.

2.1 The principle of compatibility

When analysed from the perspective of application status and trends in the world, the ISO 28560 standard will still be the principal reference standard for most countries for a considerably long time in the future. Therefore, in the process of formulating data models, one must refer to ISO 28560 and make it compatible to its later revised version concerning the structure. The defined field of user data elements needs to be completely compatible to all necessary user data elements derived from the ISO 28560 standard.

Users refer to institutional users (i.e. library users), and user data elements are elements that may be chosen and stored in the RFID tags. Except the system data elements, most of the elements can be selected.

2.2 The principle of openness

Because the application needs of university libraries are never going to be totally identical, the data model standard must be flexible and open. On the basis of obeying general principles of this standard, users can select or increase user data elements according to the practical application demand at their institution. The user data elements include necessary items and optional items. In addition to necessary items, each library can choose user data elements from the optional items, and add user data elements to the reserved items (based on the existing data element sets, they can add new data elements which have different meanings to make the existing elements possess new functions), according to their own application needs, and form suitable application models.

2.3 The principle of interoperability

A set of uniform encoding and storage rules must be defined in order that RFID suppliers can offer interchangeable and interoperable facilities or systems based on unified rules, and, therefore, guarantee the success of activities such as ILL.

To achieve the three basic principles mentioned above, the committee put forward a unified standard of university libraries for RFID tags, readers and equipment, so that the selected elements could meet the requirements of most university libraries. Because RFID tags and readers are the most fundamental and important in RFID applications, for the purpose of openness and interoperability, the Union required the RFID suppliers to separate tags, readers and equipment, and the libraries were entitled to choose and determine the standard of the tags and readers. When designing the equipment, the RFID suppliers were required to follow the standards and open the interfaces to make products from different suppliers compatible and interoperable. In 2011, the committee cooperated with RFID specialists from the School of Software at the Shanghai Jiao Tong University and collected over 40 different types of RFID tags to carry out a test for the use of their libraries. Finally, the unified RFID tags specification for university libraries had been formed after the test.

The Union has repeatedly called on university libraries to use the unified RFID data model standard. This data model completely follows the principles of compatibility, openness and interoperability. As the user data elements such as Item Identifier, Set Information and Item Location mostly come from ISO 28560, the model is completely compatible with international standards. Moreover, the model has five reserved data elements, which can be freely defined and used by libraries themselves, so the openness is obvious. With unified encoding rules, ILL and interoperation of equipment from different suppliers is possible.

3. Interpretation of tag structures

Through practical investigation, the authors found that the capacity for user data area of HF-RFID tags used in the library field is generally very large; namely, most have a capacity over 1,024 bits. However, regarding UHF-RFID tags, the user data area capacity of tags by several major chip manufacturers – such as Alien, Impinj, Semiconductor company (NXP) – is usually between 96 bits and 512 bits, which is much

smaller than that of HF-RFID tags. Hence, the capability of UHF-RFID tags must be considered in the process of data model design. This type of UHF-RFID tags cannot hold all the user data elements defined by ISO 28560.

Seen from the structure of tags, a UHF-RFID electronic tag is often divided into four areas, as shown in the four banks of Figure 1 (ISO/IEC 18000-6, 2004).

Concerning UHF-RFID tags that accord with the ISO/IEC 18000-6C standard, the four areas include: Reserved Memory, electronic product code (EPC) Storage, tag identifier (TID) and User Data. The reserved memory area mainly stores access passwords and kill passwords. The TID area chiefly stores TID codes of the tags. This code is burned into the tag when it leaves the factory and, therefore, cannot be altered. Users cannot access these two areas. Regarding library applications, the related self-defined data can only be included in the EPC storage and user data areas.

In practical work for RFID, the principles of reading and writing for the two areas are not the same. When the RFID reader sends the polling order, the content of the EPC storage area for all RFID tags in the signal areas can be totally read for one time and be returned quickly, but the content of the user data area can only be read and written by tags in batches and in blocks. Thus, the speed for reading the data of the user data area is slower than that of the EPC storage area. As a result, to use library data models better, the most frequently used data, such as barcodes, should be put in the EPC area, while the less frequently used information which is not demanding of processing time can be put

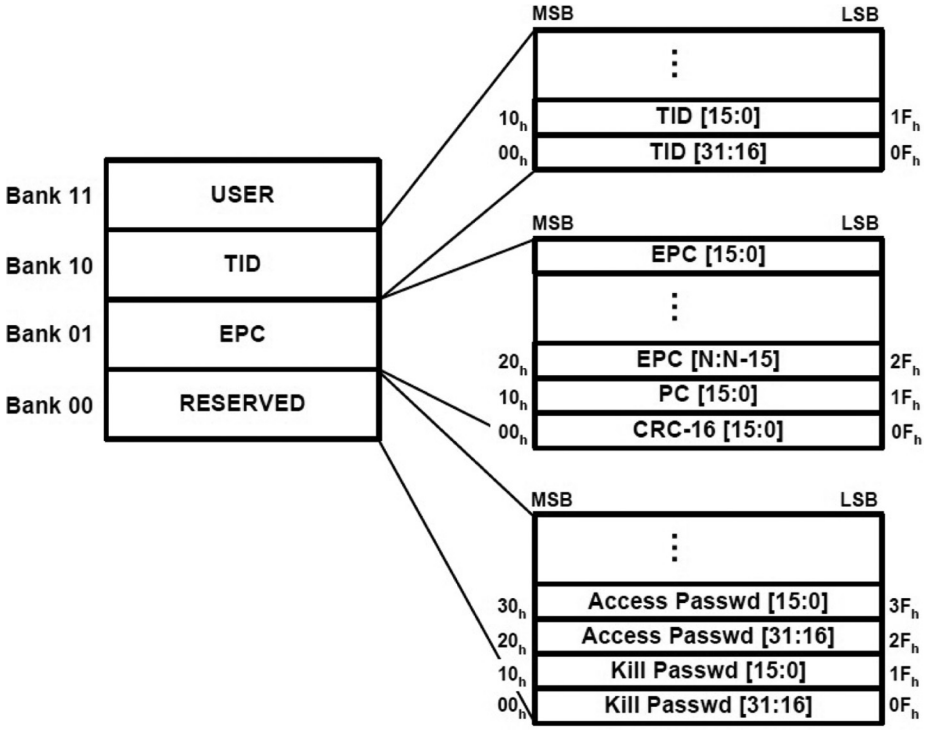

Figure 1.
Structure of UHF-RFID tags

in the user data area. This will greatly improve the reading and writing efficiency of UHF-RFID tags in practical applications.

4. Methods for the model construction

ISO 28560 is highly authoritative in the international area, so it was used as a template when designing this data model. Some modifications and expansions were done as needed to support the specific demands of university libraries and features of UHF-RFID chips. To choose the appropriate user data elements that satisfy university libraries' needs, the committee conducted a lot of research and a user survey during the drafting of the data model. A number of meetings were held to discuss and modify the data model. Survey questionnaires were performed to consult different kinds of institutions and experts, including several domestic university libraries, including the Tsinghua University Library, Peking University Library, Zhejiang University Library and so on. Additionally, six library UHF-RFID product suppliers in China, and several experts in the research field of RFID – such as Dong Xijing from the National Library of China – were also surveyed. The survey questionnaire is shown in the Appendix. The survey results are shown in Table I. The authors selected the more important results as the original survey result list is quite long. After careful consideration of the feedback and functionality demands from the university libraries in China, the committee finally selected this data model. Moreover, before the data model was released, an expert consultation meeting was held to demonstrate the feasibility and practicality of the model.

Concerning the user data elements applied in the RFID chips, a careful study of all the 31 user data elements included in ISO 28560-1 was performed. As a result, the elements were reduced to 19 with 5 newly defined ones added. The acceptance or rejection of user data elements in ISO 28560-1, and the definition and origin of the newly added elements will be elaborated on in Section 5.

Regarding the encoding rules, the authors partly adopted the methods used in ISO 28560-2 and improved them for better adaption to the features of UHF-RFID chips. The encoding rules will be explained in detail in Section 6.

5. Definition of user data elements

Altogether, ISO 28560 defines up to 31 user data elements, but they are not all completely applicable to university libraries. Accordingly, in light of ISO 28560 as well as the special application demands of university libraries, the user data elements are chosen and self-defined in the research process. Based on ISO 28560, some user data elements closely related to the practical application needs of university libraries are selected. In addition, in consideration of expansibility, a certain number of user data element entries are reserved. In total, 19 user data elements, including five reserved items, are defined, consisting of necessary entries and optional ones. Except "version (with the order number 101)", all other entries are from the international standard ISO 28560, and the sequence number is totally in accord with what ISO 28560 defines. Table II shows the basic content of all the 19 user data elements defined in this data model.

The explanations of user data elements are basically identical with definitions and descriptions from ISO 28560, thus this can be referred to in the original text of the

Respondent	Draft Chapter/Content	Comment	The committee's opinion
Huang Chen (Zhejiang University Library)	6.2.6	The two data elements, i.e. subsidiary of an owner library and item location, should be combined	Disagree. Because the two elements are separated in most ILS and the length of the elements are not the same. If we combine them, we cannot distinguish a subsidiary of an owner library from an item location in the combined elements
Dong Xijing (National Library of China)	The EPC Storage Area	ISO 28560-5 will design a unique identifier in the EPC storage area, so we should carefully use this area and try not to go against the international standard	Partially agree. We will carefully consider the storage plan according to the importance and frequency of the data elements
Nie Hua (Peking University Library)	The Content	The data model should give some guidance or examples for practical application	Agree. We will add these to the application guide
Jing Xianghu (City University of Hong Kong)	8.2 (Page 13)	According to the standard of EPC global, there is already specific storage area of AFI (ISO 15692)	Agree
Zhang Jilong (Fudan University Library)	8	It is improper to choose UHF-RFID tags for the title, as it narrows the scope of application	Agree. We will add the HF-RFID case and modify the title
Xu Qiang (Shanghai Library)	6	Why are there no multimedia data elements in this model? These elements will be useful to distinguish the type of circulation materials	Disagree. We can apply the usage data element to distinguish the type of circulation materials. As there are hardly any circulation services for CD, DVD or other multimedia resources in university libraries, there is no need to set a specific data element for multimedia materials
Feng Hanjiong (Invengo Information Technology Co., Ltd.)	8.1	TID is defined in ISO 18000-6C, and it is not equivalent to UID	Agree

Note: ILS = Integrated Library System

Table I.
Survey results for the *Draft of UHF-RFID data model specification for university libraries*

Table II. User data elements

Sequence number	Name of data elements	Display formats	Status	Description	Source
101	Version	2 bits encoded information and 6 bits version information	Mandatory	Specifies the encoded mode of item identifiers and version information of the tags	custom
1	Item identifiers	1-14 Variable-length string①	Necessary	Unique identification of an item at least inside the library; usually using barcodes	ISO 28560 + custom
2	Content index	16 bits binary code	Necessary	Specifies the structure of the tag data	ISO 28560 + custom
3	Owner library	2 byte integer	Optional	Codes for the library that owns the item	ISO 28560 + custom
4	Set information	4 byte field	Optional	Number of parts in the item and ordinal part number	ISO 28560 + custom
5	Type of usage	2 byte field	Optional	Types and usage information about the item	ISO 28560 + custom
6	Item location	Variable-length string①	Optional	Codes for location of the item	ISO 28560
11	ILL borrowing Library	Variable-length string①	Optional	Codes for the library borrowing the item	ISO 28560 + custom
12	ILL borrowing transaction number	Variable-length string①	Optional	Number identifying an interlibrary loan transaction	ISO 28560
14	Alternative item identifiers	Reserved for future use	/	Possibly encoding in new tag architecture	ISO 28560
15	Temporary item location	Variable-length string①	Optional	Codes for temporary location of the item	Custom
16	Subject	Variable-length string①	Optional	Codes for classification of the item	Custom
24	Subsidiary of an owner library	Variable-length string①	Optional	Internal codes defined within a library	ISO 28560
26	ISBN/ISSN	Variable-length string①	Optional	Identification of an item in the case of ILL situation	Custom
27	Reserved data	/	/	/	ISO 28560
28	Reserved data	/	/	/	ISO 28560
29	Reserved data	/	/	/	ISO 28560
30	Reserved data	/	/	/	ISO 28560
31	Reserved data	/	/	/	ISO 28560

Notes: ISSN = International Standard Serial Number; ISBN = International Standard Book Number

standard. This paper will mainly give a brief introduction and explanation to some definitions or descriptions of user data elements which are different from ISO 28560.

5.1 Version

This user data element is completely user-defined, so a brand new order number 101 is allocated to avoid sequence number conflict with ISO 28560. Version has the following two major functions:

(1) *Recording encoding modes of item identifiers.* This data model aims at three typical tags of the EPC storage area capacity (i.e. 96 bits, 128 bits, 144 bits, including those over 144 bits) and formulates three different encoding compression modes for item identifiers. For more details about encoding rules and codes, one can refer to the original text of the data model standard published in the Union website (Consortium for RFID Applications in Higher Education Libraries, 2013).

(2) *Recording version information of the data model.* This is used for providing updated information on the data model. In principal, the Union is responsible for controlling and releasing the information. For example, when the definition of some data elements changes greatly, the Union will revise the data model standard and issue a new version. The moment the software reads the version information of the tags, it refers to content configuration files of data models stored in the local or Union website, and gives a corresponding analysis. Therefore, different versions are compatible. In such a case, even if two libraries use different versions of data model standards, interoperability is still possible.

5.2 Identifiers for owner libraries

Within ISO 28560, the numeric value of owner library identifiers is selected by referring to the ISO 15511-ISIL standard (ISO 15511:2011, 2011). Codes for each library are made of at most 16 characters like country codes, area codes, library types and library codes. For UHF-RFID tags with its smaller capacity, this approach to select numeric value occupies too much space and is thereby impractical.

For university libraries, in *Information of Education Management – Basic Codes for Education Management* (JY/T 1001-2012, 2012 i.e. sector standard by Ministry of Education of the People's Republic of China), there is a *Code Table for Institutions of Higher Learning in China*. The codes for institutions of higher learning can be used to stand for the owner library. The whole code comprises ten digits, but actually the last five digits can be a unique representative of each university or college. Therefore, one can adopt the last five fixed length digits of the code. For instance, "Shanghai Jiao Tong University Library" can be represented by "10248".

The owner library identifier is crucial for such work as large-scale ILL circulation. Though this data element, the RFID application system can judge whether an item is owned by a certain library or not. Hence, librarians can quickly decide whether the item can be transferred automatically to such processes as ILL.

5.3 Temporary item location

This data element is designed to record a temporary item location. For instance, in an intelligent application of RFID such as smart shelves or satellite libraries, where the satellite libraries are in such places as dormitories, schools, departments and so forth,

the item in these facilities will be allocated with a corresponding temporary item location automatically. We can apply this user data element to track the actual location of corresponding items on the condition that information for the original item location does not change. Readers can see the actual item location outside the library instead of the original item location when searching through the OPAC retrieval system.

5.4 Subject

This user data element whose numeric value is selected according to the Chinese Library Classification is designed to identify the subject to which the item belongs. With the condition that the element is not interconnected with the book management system, it can read the subject classification information quickly, and thus it offers support for such activities as library services, data, statistics and so on. For example, subject librarians could access the subject classification information of items being looked at by users when the books are scanned, thus offering convenience for quick classification. Moreover, the classification information can also provide different kinds of borrowing and reading information of books with RFID tags, and therefore realize more comprehensive statistical functions.

5.5 ISBN/ISSN

The user data element ISBN or ISSN is designed to help identify an item location accurately in such circumstances as ILL. Due to limited capacity, the tags will not store the information of titles in most cases. However, this model allows for ISBN/ISSN storage, thereby acquiring title information for items swiftly in the book management system of our own library via the ISBN or ISSN in such cases as ILL. Readers, therefore, are able to identify the items conveniently in operations such as self-help borrowing and returning.

In the 19 user data elements, only the first three items are necessary, while others are all optional. Different libraries can choose from the optional elements according to their application needs. As the tag capacity is very small and is only prepared to be used for one library, only the three necessary items need to be selected. If interoperation between libraries is involved, then "owner library identifiers" must be written in the tags. In the interoperation between libraries, "version" and "content index" play an important part. Through these two necessary fields, we can accurately identify content that different libraries write in the tags, and thereby carry out reading and writing smoothly among different tags.

For university libraries, self-defined user data elements such as "subject" and "temporary item location" will play a crucial role in practical applications. If a library wants to try more intelligent subject services, then these data elements should be considered in the employment of data models.

Identical with ISO 28560, five data elements were reserved in the data model for future expansion. When the international standard changes, this data model will be revised accordingly, to realize the maximum compatibility.

6. Encoding rules

As mentioned earlier in this paper, the reading and writing principle of EPC storage area for UHF-RFID tags is different from that of the user data area, so their read-write speed is quite different from each other. This data model suggests that the frequently used user data elements which are demanding of read-write speed should be included in EPC

storage area; that is, the three necessary user data elements: Version, Item Identifiers and Content Index. As to those less frequently used user data elements that are less demanding of read-write speed, they can be included in the user data area. Because the stored content is not the same as the read-write mode, we designed dissimilar encoding rules for the two areas so as to achieve maximum work efficiency for UHF-RFID tags.

6.1 EPC storage area

Because the user data elements stored in the EPC storage area are relatively fixed, we recommend the fixed length encoding modes. "Version" and "content index" in itself belong to binary fixed-length fields, so it is unnecessary to compress the codes. For the "item identifier", (namely, the current widely used barcodes) three different kinds of encoding modes were tried which correspond to three sorts of tags with different EPC storage area capacity (that is: 96 bits, 128 bits, and 144 bits, including those over 144 bits). After investigation, we found that the encoding modes basically covered all types of present codes that university libraries used, including any character that is less than 14 bits and belongs to the character set of ISO/IEC 646 IRV.

6.2 User data area

The user data area stores optional user data elements that can be chosen by users themselves. Because the user data elements each library chooses may be different, we cannot use fixed-length encoding modes. Instead, the authors applied variable-length encoding modes based on ISO 15962 (ISO/IEC 15962, 2004) similar to those mentioned in ISO 28560-2.

While designing the data model, the authors fully considered the principle of operation for user data areas of UHF-RFID tags (i.e. "alignment by words" and "reading and storing by blocks"). The length of every user data element is designed to be a multiple of double bytes and, therefore, we can access each individual user data element easily according to "word data blocks" in the process of reading and writing.

The method of storage for user data elements in this area is in the form of variable-length blocks. Each user data element comprises "order number", "user data element length" and "user data element content". The data structure is shown in Table III below:

- *Order number:* Occupies 6 bits and corresponds to the number of user data elements of data models, reaches 64 different user data element at the most;
- *Length of user data elements:* Occupies 10 bits and can show the maximum data element length of 128 bytes;
- *Content of user data elements:* Has variable length and is decided by numeric value selection of specific user data elements. The smallest unit is 2 bytes. The

Table III. The structure of the user data area

Length (byte)	2		Variable-length (a multiple of 2 bytes)
Length (bit)	6	10	Variable-length
Structure	Order number of user data elements	Length of user data elements	Content of user data elements

elements are aligned with characters (words, double byte) while the insufficient section can be supplemented with 0.

The library can choose user data elements stored in the user data area according to their needs. The storage pattern for the data is shown in Table IV.

Unlike the reading and writing mechanism of the EPC storage area, the user data area needs to set an initial position and data length. If the user data element a library chooses is fixed, even though the longest length of the applied user data area is fixed, then the numerical value should be recorded in the configuration table of the RFID system to be called when it is written and read each time; that is, one ought to start from the initial position of user data areas only and read all the currently used longest data of the user data areas of the tags. In this situation, one need not read all the user data areas, and the reading and writing efficiency can be thus improved.

7. Evaluation and testing

The proposal of this data model will fill in a gap in the library UHF-RFID data model standard, and provide valuable reference and research ideas for further revision of ISO 28560. At first, many domestic libraries did not realize the importance of the RFID data model, but after this data model was brought forward, a number of libraries began to accept it and use it, making the circulation of books with RFID from different libraries at home and abroad possible. Hence, there will be no obstacles in reading and circulation all the RFID on books from different libraries. This offers great convenience to users.

To help with the improved application of the model, the authors designed several special user data elements which will be helpful for future big data applications, such as use analysis of books and data mining. For the designed user data elements, there are also a few forward-looking predictions which will support libraries' creative applications, such as intelligent shelves. Hopefully, this data model will lay a solid foundation for the development of *The Internet of Things* and construction of smart libraries.

The UHF-RFID data model will provide the domestic UHF-RFID product suppliers with a unified standard to follow, making the industry standard originally held or monopolized by big suppliers become open and standardized. This will enhance market competitiveness and the libraries therefore may get less expensive and better products.

The process of ILL for books with UHF-RFID using this data model is shown in Figure 2.

After the data model was put forward, the authors communicated with six library RFID product suppliers in China and tested six different UHF-RFID tags. On the basis of specified user data elements and values, the six suppliers encoded the elements based on the data model and wrote the data information onto the tag chips, then they read each other's tags with their own RFID readers to verify the data information. The testing

Order number of user data element 1	Length of user data element 1	Content of user data element 1
Order number of user data element 2	Length of user data element 2	Content of user data element 2
Order number of user data element 3	Length of user data element 3	Content of user data element 3

Notes: Reading length (Maximum length for use); total length of user data areas

Table IV.
The way of storage for the user data area

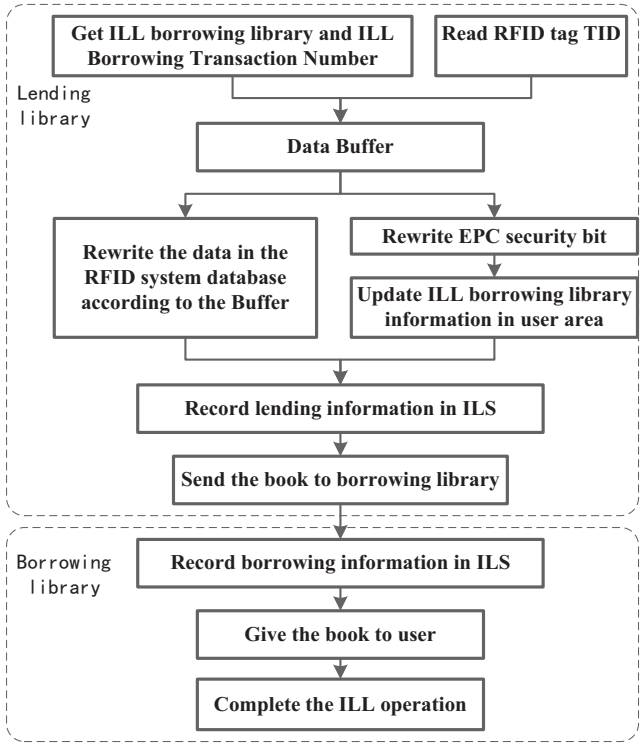

Figure 2.
The process of ILL of UHF-RFID books

results showed that the data information in these six suppliers' tags was the same, and could be read and verified by each other after the adoption of this data model.

Recently, the Shanghai Jiao Tong University Library purchased a large number of RFID tags. The librarians incorporated data from this model in the tags and put these tags into the books. Then, they shelved the books in RFID self-circulation machines, auto-sorting machines, 24-hour self-check machines and other RFID equipment. As is shown in Table V, the service condition of these machines was satisfying and all the elements worked fine. For example, the librarians included the "temporary item location" in the user data elements of some books and shelved these books in a RFID self-check machine outside the library. When readers searched the books through the library OPAC system, they could see the actual location of the books via the "temporary item location". For another example, librarians from Shanghai Jiao Tong University Library borrowed many books from domestic libraries, such as Fudan University Library and Xiamen University Library, who had rewritten the RFID tags using this data model for thousands of books, and deployed these RFID tags and equipment. They found that the books could be freely and well used through their RFID equipment, and the "identifiers for owner libraries" element showed which book it belonged to. They further applied the "ILL borrowing library" element to successfully complete the ILL process for these books.

Device names	Manufacturers	Testing result
Librarian work stations	Invengo Shanghai RFID Changzhou Kejing Claridy HKC Qingda Zhibo	All the elements designed in the model could be successfully written into the tags. We used every manufacturer's device to write data into each other's tags following the model, and the operation of reading and writing the tags was satisfying
RFID self-circulation machines	Invengo Shanghai RFID Changzhou Kejing Claridy HKC Qingda Zhibo	Books using the model could be successfully borrowed and returned through these machines
Auto-sorting machines	Invengo Changzhou Kejing HKC	Librarians could successfully sort books which followed the model into different boxes by reading the data of the sorting number in the tags
24-hour self-check machines	Invengo Changzhou Kejing HKC	Books using the model could be successfully returned via these machines
Shelf arranging machines	Invengo Changzhou Kejing Qingda Zhibo	Books on the shelves could be well arranged using the machines

Table V.
Testing results of the service condition of RFID equipment

8. Conclusion

With the development of UHF-RFID technology, more and more libraries, especially university libraries, have noticed the development potential of this technology and begun to use UHF-RFID to manage the library's daily work. The library field urgently needs "laws to abide by" and unified data model standards to comply with to standardize operations and practices, which will help organize the market. Accordingly, based on several particular application needs of university libraries and the ISO 28560 standard which is mainly designed for HF-RFID for the moment, the authors attempted to bring forward such a set of data model standards for university libraries to refer to and research further. It is hoped that the model will play its due role in the future employment of RFID.

It is likely that the International Organization for Standardization will put forward ISO 28560-4 and ISO 28560-5 standards for UHF-RFID in 2013 (Danish Agency for Culture, 2012). Regarding ISO 28560-4, it prescribes the data encoding of library UHF-RFID tags by applying an encoding scheme in the dynamic format based on the data encoding of ISO/IEC 15962, which is no longer similar to HF-RFID tags that use two encoding schemes. As to ISO 28560-5, it prescribes the long-disputed unique identifier (UID/UII) scheme for 900 MHz tags in the library field. The current data model standard will make corresponding revisions in accordance with the latest international standard, hoping to realize maximum compatibility and make UHF-RFID technology take root, spread and produce the most beautiful blossom in university libraries.

References

Chen, J., Jing, X.H. and Deng, J.K. (2005), *Library RFID Technology and Its Application*, Shanghai Jiao Tong University Press, Shanghai.

Consortium for RFID Applications in Higher Education Libraries (2013), "RFID technology application union for university libraries", available at: www.cityu.edu.hk/lib/rfid_consortium/index_e.html (accessed 15 February 2014).

Danish Agency for Culture (2012), "RFID in libraries – ISO 28560", available at: http://biblstandard.dk/rfid/ (accessed 15 February 2014).

DB 44/T 898.1-2011 (2011), RFID – Book Management – Part 1: System Structure and Application Need.

DB 44/T 898.2-2011 (2011), RFID – Book Management – Part 2: Data Structure.

ISO 15511 (2011), Information and Literature – International Standard Identifiers for Libraries and Related Organizations (ISIL).

ISO 28560-1 (2014), Information and Literature – Library Radio Frequency Identification (RFID) – Data Elements and General Principles for Implementation.

ISO 28560-2 (2014), Information and Literature – Library Radio Frequency Identification (RFID) – Encoding of Radio Frequency Identification (RFID) Data Elements based on ISO/IEC15962 Rules.

ISO 28560-3 (2014), Information and Literature – Library Radio Frequency Identification (RFID) – Fixed Length Encoding.

ISO/IEC 15962 (2013), Information Technology – Radio Frequency Identification (RFID) for Project Management (RFID) – Data Protocol: Data Coding Rules and Logical Storage Functions.

ISO/IEC 18000-6 (2004), Information Technology – RFID for Project Management – 860MHz to 960MHz Air Interface Communications Parameters.

JY/T 1001-2012 (2012), Information of Education Management – Basic Codes for Education Management.

WH/T 43-2012 (2012), Library – Radio Frequency Identification (RFID) – Data Structure – Part 1: Setting and Application Rules of Data Elements.

WH/T 44-2012 (2012), Library – Radio Frequency Identification (RFID) – Data Structure – Part 2: Encoding Schemes for Data Elements based on ISO/IEC15962.

Further reading

ISO/IEC 646 IRV-1991 (1991), Information Technology – Seven Bit Coded Character Set for ISO Information Exchange.

Appendix

Survey on *Draft of the UHF-RFID Data Model Specification for University Libraries*

In order to know about experts' comments on the UHF-RFID data model specification for university libraries and guarantee compatibility of the UHF-RFID data model, we would like to invite you to give your valuable suggestions on the following draft so as to improve the data model. Thank you.

Review topic: *Draft of the UHF-RFID Data Model Specification for University Libraries*

Drafting unit: Shanghai Jiao Tong University Library

Respondents: _____

Respondents' affiliations:_____

Mailing address:_____

Phone:_____

E-mail:_____

Review comment:

☐ Agree with the draft and no comment.

☐ There are some problems with the data model. Please refer to the following review comment table.

Review Comment Table

No.	Chapter No. of the Draft	Review Comment
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Figure A1

Corresponding author
Jing Guo can be contacted at: jguo@lib.sjtu.edu.cn