Update Method of EXI Conversion Processing conforming to ISO15118 Standard with Open Source

Yoshiaki KOHAMA

Motohide KINOSHITA

Abstract

Open source (openV2G) and commercial software, which perform EXI conversion conforming to ISO15118 standard of electric vehicle charging communication, are being used for the development of charging devices.

However, since ISO15118 standard is being reviewed to be revised, the latest version of EXI conversion software is not provided sequentially. In addition, although there is a situation where the communication has to be examined with a modified format to ISO15118 standard in development scene or others, there was an issue that development couldn't be performed flexibly because a request for commercial software development is required for this.

Therefore, in order to shorten the development period, ISO15118 standard and open source conversion specifications are studied so that in-house design development can be performed without waiting for developments of open source or commercial software. As a result, the design method, which uses unique EXI conversion conforming to the latest ISO15118 with the open source, is introduced in this article.

1. Introduction

In recent years, an electric vehicle (EV/PHEV) has attracted attention against a background of increasing interest in resource constraints and environmental issues. In order to popularize the electric vehicle, charging systems **(Fig. 1)** which is regarded as a key system and its communication method are currently being standardized **(Table 1)** in various countries/areas.

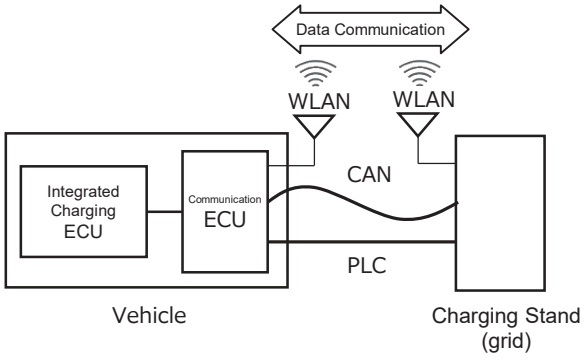

Fig. 1 Structure Diagram of Charging System

Table 1 Charging Standard and Communication Protocol in Each Country/Area

Country, Area	Japan	China	Europe	North America
Charging Standard	CHAdeMO Standard	GB Standard	Combined Charging System (CCS)	Combined Charging System (CCS)
Communication Protocol	CHAdeMO Method (CAN)	J1939 (CAN)	ISO 15118 (PLC/Wireless)	SAE J2847/2 (PLC)

We, DENSO TEN Limited, are currently developing a charging communication ECU which conforms to ISO15118 standard.

ISO15118 can be explained as follows; the standard name is "Vehicle to Grid (V2G) – Communication Interface," which is translated into Japanese as "Communication interface between the electric vehicle and a grid (power grid)." Also, the standard structure is subdivided as shown in **Table 2**, and a relationship between layer architecture of the OSI reference model and communication protocols is shown in **Fig. 2**.

Table 2 Details of ISO15118 Standard [1)]

Standard Name	Overview
ISO15118-1	General information and use-case definition
ISO15118-2	Network and application protocol requirements
ISO15118-3	Physical and data link layer requirements
ISO15118-4	Network and application protocol conformance test
ISO15118-5	Physical and data link layer conformance test
ISO15118-6	General information and use-case definition for wireless communication
ISO15118-7	Network and application protocol requirements for wireless communication
ISO15118-8	Physical layer and data link requirements for wireless communication

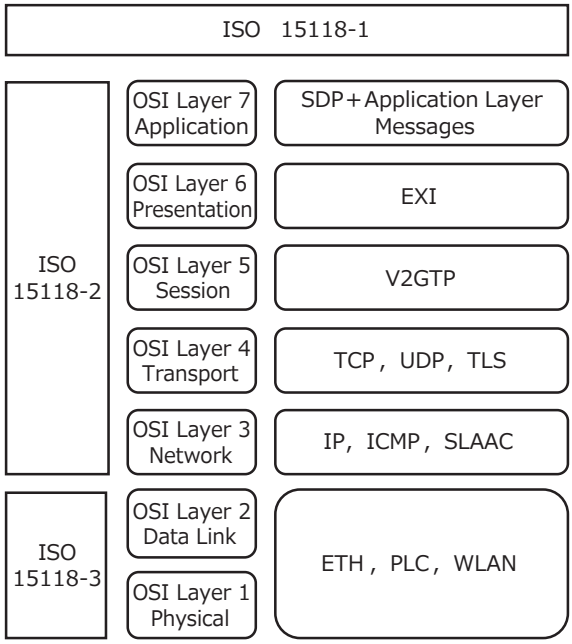

Fig. 2 Relationship among ISO15118, OSI Reference Model, and Protocol [1)]

OpenV2G [4)], which is an open source implementing basic functions of the Vehicle to Grid (V2G) communication interface defined in ISO15118, is utilized to realize the function in our development, and **Fig. 3** shows the structure of a charging communication software.

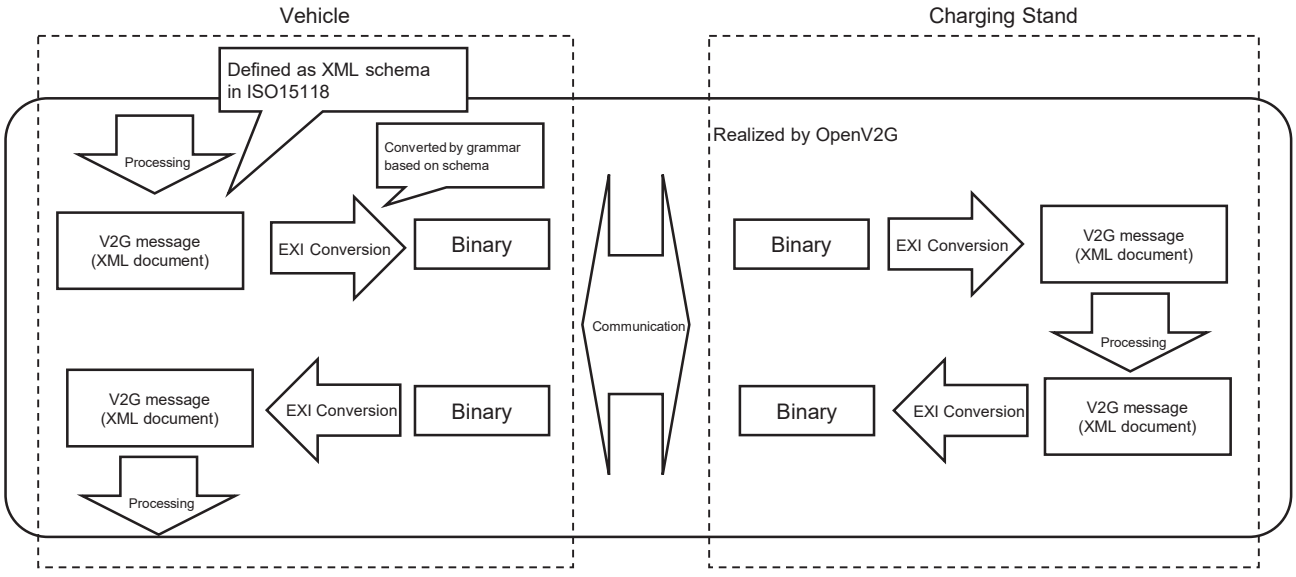

Fig. 3 Software Structure of Charging Communication

Although our development status is currently under trial development, it is necessary, for example, to wait for an open source revision to develop the charging communication system each time a standard change proposal is released because the ISO15118 standard is still at the stage where the draft is being revised. Accordingly, there was an issue that a time lag occurred in development.

Therefore, in order to independently develop the system as with the open source, changing XML schema of the ISO15118 standard and understanding EXI conversion processing which conforms to a grammar based on the schema (Schema-informed Grammars) were needed. For that reason, we investigated the technology and procedure necessary for it.

2. EXI Structure of ISO15118 Standard

EXI is used in Layer6 presentation layer of the OSI reference model and is specified in the ISO15118-2 of network and application protocol requirements. Also, EXI expresses the contents of XML document as an EXI stream in binary format and has a structure that EXI Header is followed by EXI Body.

2.1 EXI Header

EXI Header stores information necessary for decoding the EXI body. The minimum header is represented by 1byte, and for Open V2G, it is 1byte data of the minimum header **(Fig. 4)**.

2.2 EXI Body

In EXI Body, XML V2G communication message is stored after binary conversion, and the conversion method which is used in the ISO15118 standard is the grammar based on the schema. Accordingly, encoding is performed separately for the Structure and Contents based on this grammar, and then the EXI stream is converted to binary data and stored in the EXI Body by arranging its result in order. The outline is shown in **Fig. 5**.

EXI Header Structure　※[] can be omitted

[EXI Cookie]	Distinguishing Bits	Presence Bit for EXI Options	EXI Format Version	[EXI Options]	[Padding Bits]
Value in OpenV2G (bit) ⇒ 0x80					
-	10	0	0 0000	-	-

Fig. 4　EXI Header Structure and Value of OpenV2G [2)]

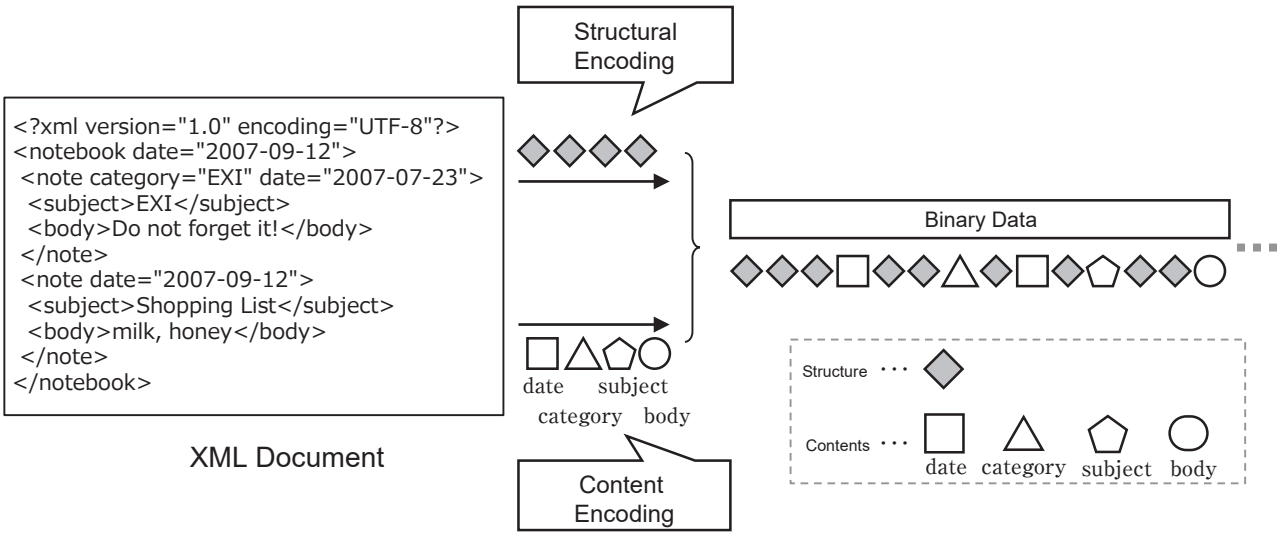

Fig. 5　EXI Body Stream [3)]

3. EXI Conversion and Differential Development

For the charging sequence of ISO15118 standard, the message to be used is called V2G message, which is described in the XML format and is sent/received after being encoded into binary by the EXI conversion. In addition, the V2G message to be used is defined as the XML schema in the ISO15118-2 standard, and its XML schema is used in OpenV2G and the EXI conversion using the grammar based on the schema are performed.

Therefore, the know-how of the EXI conversion method was derived by comparing the ISO 15118 standard and the OpenV2G source in order to reach the EXI conversion method.

3.1 Structural Encoding

V2G communication message is composed of the following two different message sets; V2G application layer protocol handshake message and V2G application layer message, and each has the XML schema.

First of all, in structural encoding, a corresponding pushdown automaton is created from the above XML schema. **Fig. 6** shows examples of the XML schema and the created pushdown automaton.

Next, encoding is performed by attaching an event code to each event from the created pushdown automaton. **Fig. 7** shows the result of encoding by attaching the event code from **Fig. 6**.

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified">
 <xs:element name="notebook">
  <xs:complexType>
   <xs:sequence maxOccurs="unbounded">
    <xs:element name="note" type="Note"/>
   </xs:sequence>
   <xs:attribute ref="date" />
  </xs:complexType>
 </xs:element>
 <xs:complexType name="Note">
  <xs:sequence>
   <xs:element name="subject" type="xs:string"/>
   <xs:element name="body" type="xs:string"/>
  </xs:sequence>
  <xs:attribute ref="date" use="required" />
  <xs:attribute name="category" type="xs:string"/>
 </xs:complexType>
 <xs:attribute name="date" type="xs:date"  />
</xs:schema>
```

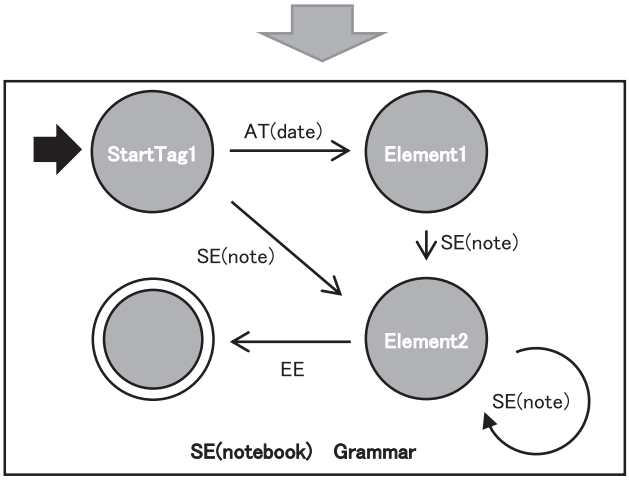

Fig. 6　Example of XML Schema and Corresponding Grammar [3)]

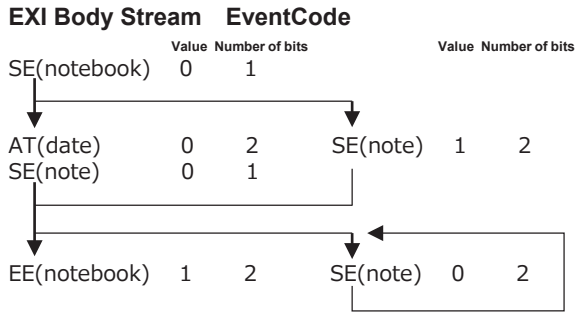

Fig. 7 SE (notebook) Event Code [3)]

The creation method of the specific pushdown automaton and encoding of event codes are summarized as ① to ⑩ below.

①EXI Event Type **(Table 3)** allocation is performed from the XML schema. However, only Start Element, End Element, Attribute, and Characters shall be used for ISO15118 standard.

②All complex type (with a structure) elements which are described in the XML schema are registered on the pushdown automaton of DocContent. Event codes are assigned in alphabetical order of element names.

③The pushdown automaton corresponding to each complexType (with a structure) element are created, and a tree structure is decomposed until the element types become a simpleType (without a structure) element.

④The order of elements to be included shall be the order from the top between tags when there is a sequence tag, and the alphabetical order of the element names is applied when there is no sequence tag.

⑤The element without minOccurs and maxOccurs in the sequence tag of XML schema is required in the sense of the number of elements from the minimum 1 to the maximum 1, and must contain its element. Accordingly, the event code of the required element is unique and is set with a value of 0 and a bit number of 1.

⑥The element for which minOccurs="0" is described in the sequence tag of XML schema is optional in the sense of the number of elements from the minimum 0 to the maximum 1. In the case of the optional element, it is branched due to the occurrence of the presence or absence of an element, and a value is assigned to each event code for each branching pattern.

⑦The element for which maxOccurs="??" (?? is a number) is described in the sequence tag of the XML schema is a list in the sense of the number of elements from the minimum 1 to the maximum??. In the case of the list, it is expressed by branching and repeating the element, and a value is assigned to each event code depending on whether or not there is a next list.

⑧The element in a choice tag of the XM schema is branched to select one of the elements in the choice. The event code is assigned to each element in order from the top so that one of them can be selected.

⑨AT of the XML schema is outside the sequence and the choice tag, and the order shall precede the elements in the sequence and the choice. In addition, outside the sequence and the choice tag, it is required if use="required" is described. On the other hand, it

Table 3 EXI Event Type List

EXI Event Type	Grammar Notation	Remarks
Start Document	SD	Omitted in grammar based on ISO15118
End Document	ED	Omitted in grammar based on ISO15118
Start Element	SE (qname)	
	SE (uri:*)	
	SE (*)	
End Element	EE	
Attribute	AT (qname)	
	AT (uri:*)	
	AT (*)	
Characters	CH	
Namespace Declaration	NS	Not exist in XML schema of ISO15118
Comment	CM	Not exist in XML schema of ISO15118
Processing Instruction	PI	Not exist in XML schema of ISO15118
DOCTYPE	DT	Not exist in XML schema of ISO15118
Entity Reference	ER	Not exist in XML schema of ISO15118
Self Contained	SC	Not exist in XML schema of ISO15118

is optional if use = "required" is not described. The event code of AT is required in the same way as the element and is assigned according to the optional branch.

⑩If there is a substitutionGroup (Replaceable element) in the element of the XML schema, the elements including the original element are branched so that one of the replaceable elements can be selected. Event codes are assigned to each element including the original element in alphabetical order so that one of them can be selected.

3.2 Content Encoding

For content encoding, the EXI conversion encoding is performed corresponding to data types of the XML schema. Since the encoding of the EXI conversion for each data type has already been implemented in open source (OpenV2G), the processing is used as it is. **Table 4** shows a list of OpenV2G function corresponding to the data types of the XML schema.

For a string type, it is converted to a number instead of a string if "enumeration" is described. In addition, Event type including the content are only AT and CH, and the event code is determined along the branch because AT is optional like elements. Furthermore, since CH is always sandwiched between SE and EE, the event code is unique and is set with a value of 0 and a bit number of 1.

4. Conclusion

In this article, we investigated the open source (OpenV2G) of ISO15118 standard and the EXI conversion standard, and then described the procedure for responding to the latest ISO15118 standard and performing the development of the EXI conversion of an incompatible local format, which are based on the open source. As a result, we could acquire basic technology to design and develop all the EXI conversion processing by learning the technology capable of developing the EXI conversion. Furthermore, for a risk which comes from not knowing when the open source will be revised at the time of the revision of ISO15118 standard, there is an advantage that the operation can be examined in advance by designing and developing based on the contents described in this article.

In future, we would like to learn more technologies through the actual development in the case of changing the standard.

Table 4　List of Open Source (OpenV2G) Corresponding to XML Schema Data Type

EXI Data Representation	XML Schema Data Type	Corresponding OpenV2G Function
Binary	base64Binary, hexBinary	encodeBinary, decodeBinary
Boolean	boolean	encodeBoolean, decodeBoolean
Date-Time	dateTime, time, date, gYearMonth, gYear, gMonthDay, gDay, gMonth	encodeDateTime, decodeDateTime
Decimal	decimal	encodeDecimal, decodeDecimal
Float	float, double	encodeFloat, decodeFloat
n-bit Unsigned Integer	Integer with a boundary range of 4096 or less, which is determined by facet values of minInclusive, minExclusive, maxInclusive, and maxExclusive	encodeNBitUnsignedInteger decodeNBitUnsignedInteger
Unsigned Integer	nonNegativeInteger or integer which has the minInclusive facet specified with a value greater than 0 or minExclusive facet specified with a value greater than -1	encodeUnsignedInteger decodeUnsignedInteger
Integer	n-bit unsigned integer, or any other unsigned integer which is not yet covered	encodeInteger, decodeInteger
String	All types which are directly derived from tring, anySimpleType, and union	encodeString, decodeString
List	All types which are directly derived from the list such as NMTOKENS, IDREFS, and ENTITIES	Function corresponding to the data type which makes up the list
QName	The value of xsi: type attribute in the case where the Preserve.lexicalValues option value is false: value of the type attribute	encodeString encodeNBitUnsignedInteger decodeString decodeNBitUnsignedInteger

Reference

1) ISO 15118-2:2014 Road vehicles — Vehicle-to-Grid Communication Interface — Part 2: Network and application protocol requirements, ISO TC 22/SC 31
2) Efficient XML Interchange (EXI) Format 1.0 (Second Edition), 2014-02-11, W3C
http://www.w3.org/TR/exi/
3) Efficient XML Interchange (EXI) Primer, 2014-04-24, W3C
http://www.w3.org/TR/exi-primer/
4) OpenV2G Website
http://openv2g.sourceforge.net/

Profiles of Writers

Yoshiaki
KOHAMA

DENSO TEN
TECHNOLOGY
Limited

Motohide
KINOSHITA

DENSO TEN
TECHNOLOGY
Limited