Validation of bitstream syntax and synthesis of parsers in the MPEG Reconfigurable Video Coding framework
Mickaël Raulet, Jonathan Piat, Christophe Lucarz, Marco Mattavelli

To cite this version:

HAL Id: hal-00340390
https://hal.archives-ouvertes.fr/hal-00340390
Submitted on 20 Nov 2008

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
VALIDATION OF BITSTREAM SYNTAX AND SYNTHESIS OF PARSERS IN THE MPEG RECONFIGURABLE VIDEO CODING FRAMEWORK

Mickaël Raulet, Jonathan Piat
Institut d’Electronique et de Télécommunications de Rennes (IETR)
UMR CNRS 6164 (France)
Email: mraulet@insa-rennes.fr

Christophe Lucarz, Marco Mattavelli
Microelectronic Systems Laboratory (GR-LSM)
Ecole Polytechnique Fédérale de Lausanne (Switzerland)
{christophe.lucarz,marco.mattavelli}@epfl.ch

ABSTRACT
Video coding technology has evolved in the past years into a variety of different and complex algorithms. So far the specification of such standard algorithms has been done case by case providing monolithic textual and reference SW specifications, but without any attention on commonalities and the possibility of incremental improvements or modifications of such monolithic standards. The MPEG Reconfigurable Video Coding (RVC) framework is a new ISO standard, currently under development aiming at providing video codec specifications at the level of library functions instead of monolithic algorithms. The possibility of selecting a subset of standard coding algorithm to specify a decoder that satisfies application specific constraints is very attractive. However, such possibility of reconfigure codecs requires systematic procedures and tools capable of describing the new bitstream syntaxes of such new codecs. Moreover, it is also necessary to generate the associated parsers that are capable of parsing the new bitstream syntaxes instead of monolithic parsers. The challenge taken by the Reconfigurable Video Coding (RVC) framework currently under development by MPEG is to provide a high level specification model for direct and efficient software and hardware synthesis.

The essential elements of the RVC framework are the following:

1. A library of video coding tools, also called Functional Units (FUs) covering all MPEG standards (the “MPEG Toolbox”). This library is specified and provided using CAL as specification language for each library component (i.e. video coding tool) CAL is a language used to define the behavior of dataflow components called actors, which is a modular component that encapsulates its own state such that an actor can neither read nor modify the state of any other actor. The only interaction between actors is via messages (known in CAL as tokens) which are passed from an output of one actor to an input of another. The behavior of an actor is defined in terms of a set of actions, transactional program fragments, at most one of which may be active at any point in time. The operations an action can perform are to consume (read) input tokens, modify in-
An important problem faced by RVC is how to describe and specify a new bitstream syntax and how to generate automatically software and hardware descriptions of this abstract model.

In the RVC framework, BSDL is used to fully describe the structure of a bitstream with an XML document named BS Description. For instance, in the case of a MPEG-4 AVC video codec, a BS Schema describes the structure common to all possible conformant MPEG-4 AVC video bitstreams, whereas a BS description describes a single MPEG-4 AVC encoded bitstream as a XML document. Figure 2(a) shows the BSDL Schema associated with the BS Description in Figure 2(b). BSDL uses XML to describe the structure of video coded data. An encoded video bitstream can be described as a sequence of binary symbols of arbitrary length – some symbols contain a single bit, while others contain many bytes. For these binary symbols, the BSDL Description indicates values in a human – and machine – readable format – for example, using hexadecimal values (as for startCode in Figure 2(a)), integers, or strings. It also organizes the symbols into a hierarchical structure that reflects the data semantic interpretation.

In other words, the BSDL Description level of granularity can be fully customized to the application requirements. BSDL was originally conceived and designed to enable adaptation of scalable multimedia content in a format-independent manner. In the RVC framework, BSDL is used to fully describe the entire bitstream – each elementary bit has its corresponding value in a Variable Length Decoding (VLD) table. As a result, the corresponding BS schema must specify all components of the syntax at a finer granularity level than the ones developed and used for adaptation of scalable content. In this context BSDL does not replace the original data, but instead provides additional information (or metadata) to support an application for parsing and processing the binary content. Finally, BSDL does not mandate the names of the elements in the BSDL Description; the application assigns names that provide meaningful semantics for the description at hand. Figure 2(a) is an example BSDL Description for video in MPEG-4 AVC format.

In the RVC framework, BSDL is preferred over Flavor [?].
because:

- it is stable and already defined by an international standard;
- the XML-based syntax integrates well with the XML syntax used to describe the configuration of the RVC decoder; constituted by the instantiation of FUs from the toolbox and by their connectivty
- the RVC bitstream parser may be easily derived by transforming the BSDL schema using standard tools (e.g. XSLT).

Moreover, it is certainly not a good idea to have to write it by hand when a systematic solution for deriving such parsing procedure from the BSDL schema itself could be developed. Such procedure based on transforming the BSDL schema by a XSLT transformation is describes in the second part of the paper. So being able to validate a parsing procedure (written by hand or automatically generated) using some instances of a given syntax is an important step for the RVC framework.

3. VALIDATION OF A BSDL SCHEMA BITSTREAM SYNTAX DESCRIPTION

3.1. Procedure of validation

The generic character of BSDL, and hence its merit, lies in the media format-independent nature of the different software modules that are responsible for the creation of the BS Descriptions (BSDs) and for the generation of the adapted bitstreams. The BSD generator and bitstream generator are named BintoBSD Parser and BSDtoBin Parser, respectively. Figure 2 summarizes the overall method for validating a BS schema. Explanatory notes for this figure are provided below:

1. a bitstream syntax schema (BS Schema) contains a description of the low-level syntax in RVC of a particular media format;
2. a BSD is created by a format-independent BintoBSD Parser, taking as input a particular bitstream and a corresponding BS Schema;
3. a BSD is transformed to meet the constraints of a usage environment;
4. a format-independent BSDtoBin Parser creates the original bitstream, using the transformed BSD and the BS Schema.

There are two possibilities to compare the efficiency of the schema:

1. the original bitstream is compared to the one produced by the identity operation “bintoBSD-BSDtoBin”; this bitstream should give the same decoded sequence as the original one.
2. the BSD description generated after the first “bintoBSD” operation could be compared to the identity operation “BSDtoBin-bintoBSD”. You should exactly obtain the same BS Descriptions.

A BS Schema contains a minimal amount of information such that BSDtoBin can convert each element value in a BSD to a bit-level representation. Such functionality can already be provided by an XML Schema using BSDL-1 datatypes, as BSDL-2 is specific for BintoBSD and not relevant for BSDtoBin. Thus, BSDtoBin may still be used for generating a bitstream to support BSDL-2.

![NALUnit]

(a) BS description fragment of an MPEG-4 AVC bitstream

![BS schema fragment of MPEG-4 AVC codec]

(b) BS schema fragment of MPEG-4 AVC codec

Fig. 2. BSD description and schema
3.2. User-defined data types

This subsection specifies an optional implementation mechanism for user-defined data types, that a conformant BSDtoBin or BintoBSD parser does not have to implement. But if an ECMAScript implementation of the bs1:codec data types is provided, the parser shall conform to this clause. Data types referenced by the bs1:codec in a BS Schema may be implemented using ECMAScript and the implementation is embedded in the BS Schema via the bs1:script component. This allows arbitrary parsing algorithms to be specified by a BS Schema for use by BintoBSD and BSDtoBin parsers, enabling the processing of data structures that cannot be specified using other BSDL syntax elements. The bs1:script component defines the local name of the datatype, which inherits the target namespace of the schema document. The bs1:codec attribute can then reference this implementation via the URI of the datatype, which is obtained by adding the appending the local name as fragment identifier to the namespace.

ECMAScript datatypes may be used to allow a BSDL Parser to process Variable Length Codes, such as Huffman codes or Arithmetic-coded values (Figure 5). An ECMAScript implementation may be referenced by the bs1:codec in the following ways:

- The value of bs1:codec is a URL that resolves to a BS Schema, with a fragment identifier corresponding to the value of an id attribute on a bs1:script element;
- The value of bs1:codec is a URL that resolves to an ECMAScript file, with a fragment identifier corresponding to the name of a class within that file; or
- The value of bs1:codec is a URL that resolves to an ECMAScript file, with no fragment identifier.

In each case, a BSDtoBin parser shall search the bs1:script element, class or file (respectively) for a function (or method) with the signature BSDtoBin(). The parser shall call this function to generate the element to which bs1:codec is attached, the BSDtoBin() function shall return either a string containing the lexical value of the element, or a DOM Element representing the element.

**read(bits)** This function shall be provided by a BintoBSD parser and may be called by the BintoBSD() function of a bs1:script component. When this function is called, a BintoBSD shall read from the bitstream the number of bits specified by the integer value of the bits parameter, and return the unsigned integer value of the bits read.

**write(value,bits)** This function shall be provided by a BSDtoBin parser and may be called by the BSDtoBin(value) function of a bs1:script component.

**xpath(exp,type)** This function shall be provided by a BintoBSD parser and may be called by the BintoBSD() function of a bs1:script component. When this function is called, a BintoBSD shall execute the XPath expression declared by the string value of the exp parameter, and return the value of the result of the expression. The expression shall be evaluated in the context of the partially instantiated BSDL.

(a) Javascript call outside BintoBSD tool

```
<xsd:complexType name="expGolomb">  
  <xsd:extension base="xsd:unsignedInt">  
    <xsd:attribute ref="bs1:codec" default="expGolomb.js"/>  
  </xsd:extension>  
</xsd:simpleContent>
</xsd:complexType>
```

(b) Java Class call inside BintoBSD tool

```
<xsd:complexType name="expGolomb">  
  <xsd:extension base="xsd:unsignedInt">  
    <xsd:attribute ref="bs1:codec" default="urn:mpeg:example:myLibrary#expGolomb"/>  
  </xsd:extension>  
</xsd:simpleContent>
</xsd:complexType>
```

Fig. 4. Implementation of expgolomb function

In the case you use ECMAScript implementation in your schema, you will have to validate your script in the two ways: bintoBSD and BSDtoBin.

The following implementation of Expglomb does not need but only one ECMAScript file containing 2 parts:

- the ECMAScript function called by bintoBSD (Figure 5(a)).
• the reverse ECMAScript function called by BSDtobin (Figure 5(b)).

```javascript
function BintoBSD() {
  var nBits = 0;
  var ret = 0;
  while ((ret = read(1)) == 0) nBits++;
  //read 0's
  if (ret == -1) throw "userType Error";
  ret = read(nBits);
  //read the rest
  if (ret == -1) throw "userType Error";
  return ((1 << nBits) - 1 + ret) + ""; //toString
}
```

(a) ECMAScript implementation of expgolomb for bintoBSD tool

```javascript
function BSDtoBin(value) {
  var nBits = 0;
  var tmp = value + 1;
  while ((tmp >>= 1) > 0) nBits++;
  //count how many zeros to write
  tmp = 1;
  var i = 0;
  for (i = 0; i < nBits; i++) {
    tmp <<= 1;
  }
  write(0, nBits); //write leading zeros
  write(1, 1); //write a one
  write(value + 1 - tmp, nBits); //write rest of code
  return (2 * nBits + 1);
}
```

(b) ECMAScript implementation of expgolomb for BSDtoBin tool

Fig. 5. ECMAScript implementation of expgolomb function

4. SYNTHESIS OF A PARSER IN CAL FROM A BSDL SCHEMA DESCRIPTION

Since writing a complete parser by hand beside burdensome, time consuming and error prone is certainly not a useful solution for a RVC terminal, that receives a new codec configuration made of standard components and a BSDL description of the bitstream syntax that need to be decoded. A systematic method has been conceived for automatically generate a parser in CAL from the bitstream schema (in BSDL). This idea has been first presented in [?]. Figure 7 illustrates the different steps of the transformation process and an example of the result of the generation. The advantage of generating the parser in CAL is that all the decoder model is described in the same formalism and from such form direct synthesis of the CAL decoder model to SW or HW implementations can be performed [?, ?]. The reader can also refer to [?] for a more detailed background and further details on the parser generation process.

Figure 8 shows an example of bistream schema from which a parser has been generated. The results in terms of generated CAL code that execute the bitstream parsing are shown in figure 6.

Each time a syntax element is met by the parser, the process generates a xxxx.read” action. If this element of syntax must be presented at the output by the parser, a xxxx.output’
action is created. When the parser meets a variable length code, it creates a series of actions which are necessary to communicate with the VLD FUs: xxxx.read" to read the bit from the input port, xxxx.output" to send the bit to the VLD table, and xxxx.finished" / xxxx.notfinished" to decide if the variable length code is finished or if the parser must send another bit. To get more information of the implementation of variable length decoding process in RVC, the reader can refer to the paper [?].

5. CONCLUSION

This paper describes a possible systematic methodology for the validation of a BSDL schema describing the syntax of a binary bitstream. Validation of a BSDL schema is a fundamental element of the RVC framework. A validated schema is the input of a tool that enables the automatic generation of a CAL parser that can complete the model used to specify decoders in the RVC framework.

6. REFERENCES


