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Binary Encodings for JavaScript Object Notation: JSON-B, JSON-C, JSON-D

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Abstract

Three binary encodings for JavaScript Object Notation (JSON) are presented. JSON-B (Binary) is a strict superset of the JSON encoding that permits efficient binary encoding of intrinsic JavaScript data types. JSON-C (Compact) is a strict superset of JSON-B that supports compact representation of repeated data strings with short numeric codes. JSON-D (Data) supports additional binary data types for integer and floating-point representations for use in scientific applications where conversion between binary and decimal representations would cause a loss of precision.

This document is also available online at http://mathmesh.com/Documents/draft-hallambaker-jsonbcd.html [1] .

Status of This Memo

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1. Introduction

JavaScript Object Notation (JSON) is a simple text encoding for the JavaScript Data model that has found wide application beyond its original field of use. In particular JSON has rapidly become a preferred encoding for Web Services.

JSON encoding supports just four fundamental data types (integer, floating point, string and boolean), arrays and objects which consist of a list of tag-value pairs.

Although the JSON encoding is sufficient for many purposes it is not always efficient. In particular there is no efficient representation for blocks of binary data. Use of base64 encoding increases data volume by 33%. This overhead increases exponentially in applications

where nested binary encodings are required making use of JSON encoding unsatisfactory in cryptographic applications where nested binary structures are frequently required.

Another source of inefficiency in JSON encoding is the repeated occurrence of object tags. A JSON encoding containing an array of a hundred objects such as {"first":1,"second":2} will contain a hundred occurrences of the string "first" (seven bytes) and a hundred occurrences of the string "second" (eight bytes). Using two byte code sequences in place of strings allows a saving of 11 bytes per object without loss of information, a saving of 50%.

A third objection to the use of JSON encoding is that floating point numbers can only be represented in decimal form and this necessarily involves a loss of precision when converting between binary and decimal representations. While such issues are rarely important in network applications they can be critical in scientific applications. It is not acceptable for saving and restoring a data set to change the result of a calculation.

1.1. Objectives

The following were identified as core objectives for a binary JSON encoding:

- o Easy to convert existing encoders and decoders to add binary support

- o Efficient encoding of binary data

- o Ability to convert from JSON to binary encoding in a streaming mode (i.e. without reading the entire binary data block before beginning encoding.

- o Lossless encoding of JavaScript data types

- o The ability to support JSON tag compression and extended data types are considered desirable but not essential for typical network applications.

Three binary encodings are defined:

JSON-B (Binary) Encodes JSON data in binary. Only the JavaScript data model is supported (i.e. atomic types are integers, double or string). Integers may be 8, 16, 32 or 64 bits either signed or unsigned. Floating points are IEEE 754 binary64 format [IEEE754] . Supports chunked encoding for binary and UTF-8 string types.

JSON-C (Compact) As JSON-B but with support for representing JSON tags in numeric code form (16 bit code space). This is done for both compact encoding and to allow simplification of encoders/decoders in constrained environments. Codes may be defined inline or by reference to a known dictionary of codes referenced via a digest value.

JSON-D (Data) As JSON-C but with support for representing additional data types without loss of precision. In particular other IEEE 754 floating point formats, both binary and decimal and Intel's 80 bit floating point, plus 128 bit integers and bignum integers.

Each encoding is a proper superset of JSON, JSON-C is a proper superset of JSON-B and JSON-D is a proper superset of JSON-C. Thus a single decoder MAY be used for all three new encodings and for JSON. Figure 1 shows these relationships graphically:

[[This figure is not viewable in this format. The figure is available at http://mathmesh.com/Documents/draft-hallambaker-jsonbcd.html [2].]]

Encoding Relationships.

2. Definitions

This section presents the related specifications and standard, the terms that are used as terms of art within the documents and the terms used as requirements language.

2.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

2.2. Defined Terms

The terms of art used in this document are described in the Mesh Architecture Guide [draft-hallambaker-mesh-architecture] .

2.3. Related Specifications

The JSON-B, JSON-C and JSON-D encodings are all based on the JSON grammar [RFC7159] . IEEE 754 Floating Point Standard is used for encoding floating point numbers [IEEE754] ,

2.4. Terminology

No new terms of art are defined

3. Extended JSON Grammar

The JSON-B, JSON-C and JSON-D encodings are all based on the JSON grammar [RFC7159] using the same syntactic structure but different lexical encodings.

JSON-B0 and JSON-C0 replace the JSON lexical encodings for strings and numbers with binary encodings. JSON-B1 and JSON-C1 allow either lexical encoding to be used. Thus any valid JSON encoding is a valid JSON-B1 or JSON-C1 encoding.

The grammar of JSON-B, JSON-C and JSON-D is a superset of the JSON grammar. The following productions are added to the grammar:

x-value Binary encodings for data values. As the binary value encodings are all self delimiting

x-member An object member where the value is specified as an X-value and thus does not require a value-separator.

b-value Binary data encodings defined in JSON-B.

b-string Defined length string encoding defined in JSON-B.

c-def Tag code definition defined in JSON-C. These may only appear before the beginning of an Object or Array and before any preceding white space.

c-tag Tag code value defined in JSON-C.

d-value Additional binary data encodings defined in JSON-D for use in scientific data applications.

The JSON grammar is modified to permit the use of x-value productions in place of (value value-separator) :

```
JSON-text = (object / array)

object = *cdef begin-object [
         *( member value-separator | x-member )
         (member | x-member) ] end-object

member = tag value
x-member = tag x-value

tag = string name-separator | b-string | c-tag

array = *cdef begin-array [  *( value value-separator | x-value )
 (value | x-value) ] end-array

x-value = b-value / d-value

value = false / null / true / object / array / number / string

name-separator  = ws %x3A ws  ; : colon
value-separator = ws %x2C ws  ; , comma
```

Figure 1

```
The following lexical values are unchanged:
begin-array     = ws %x5B ws  ; [ left square bracket
begin-object    = ws %x7B ws  ; { left curly bracket
end-array       = ws %x5D ws  ; ] right square bracket
end-object      = ws %x7D ws  ; } right curly bracket

ws = *( %x20 %x09 %x0A  %x0D )

false = %x66.61.6c.73.65   ; false
null  = %x6e.75.6c.6c      ; null
true  = %x74.72.75.65      ; true
```

Figure 2

The productions number and string are defined as before:

```
number = [ minus ] int [ frac ] [ exp ]
decimal-point = %x2E       ; .
digit1-9 = %x31-39         ; 1-9
e = %x65 / %x45            ; e E
exp = e [ minus / plus ] 1*DIGIT
frac = decimal-point 1*DIGIT
int = zero / ( digit1-9 *DIGIT )
minus = %x2D               ; -
plus = %x2B                ; +
zero = %x30                ; 0

string = quotation-mark *char quotation-mark
char = unescaped /
escape ( %x22 / %x5C / %x2F / %x62 / %x66 /
%x6E / %x72 / %x74 /  %x75 4HEXDIG )

escape = %x5C              ; \
quotation-mark = %x22      ; "
unescaped = %x20-21 / %x23-5B / %x5D-10FFFF
```

Figure 3

4. JSON-B

The JSON-B encoding defines the b-value and b-string productions:

```
b-value = b-atom | b-string | b-data | b-integer |
b-float

b-string = *( string-chunk ) string-term
b-data = *( data-chunk ) data-last

b-integer = p-int8 | p-int16 | p-int32 | p-int64 | p-bignum16 |
n-int8 | n-int16 | n-int32 | n-int64 | n-bignum16

b-float = binary64
```

Figure 4

The lexical encodings of the productions are defined in the following tables where the column 'tag' specifies the byte code that begins the production, 'Fixed' specifies the number of data bytes that follow and 'Length' specifies the number of bytes used to define the length of a variable length field following the data bytes:

Production	Tag	Fixed	Length	Data Description
string-term	x80	-	1	Terminal String 8 bit length
string-term	x81	-	2	Terminal String 16 bit length
string-term	x82	-	4	Terminal String 32 bit length
string-term	x83	-	8	Terminal String 64 bit length
string-chunk	x84	-	1	Terminal String 8 bit length
string-chunk	x85	-	2	Terminal String 16 bit length
string-chunk	x86	-	4	Terminal String 32 bit length
string-chunk	x87	-	8	Terminal String 64 bit length
data-term	x88	-	1	Terminal String 8 bit length
data-term	x89	-	2	Terminal String 16 bit length
data-term	x8A	-	4	Terminal String 32 bit length
data-term	x8B	-	8	Terminal String 64 bit length
data-term	X8C	-	1	Terminal String 8 bit length
data-term	x8D	-	2	Terminal String 16 bit length
data-term	x8E	-	4	Terminal String 32 bit length
data-term	x8F	-	8	Terminal String 64 bit length

Table 1

Table 1: Codes for String and Data items

Production	Tag	Fixed	Length	Data Description
p-int8	xA0	1	-	Positive 8 bit Integer
p-int16	xa1	2	-	Positive 16 bit Integer
p-int32	xa2	4	-	Positive 32 bit Integer
p-int64	xa3	8	-	Positive 64 bit Integer
p-bignum16	Xa7	-	2	Positive Bignum
n-int8	xA8	1	-	Negative 8 bit Integer
n-int16	xA9	2	-	Negative 16 bit Integer
n-int32	xAA	4	-	Negative 32 bit Integer
n-int64	xAB	8	-	Negative 64 bit Integer
n-bignum16	xAF	-	2	Negative Bignum
binary64	x92	8	-	IEEE 754 Floating Point Binary 64 bit
b-value	xB0	-	-	True
b-value	xB1	-	-	False
b-value	xB2	-	-	Null

Table 2

Table 2: Codes for Integers, 64 Bit Floating Point, Boolean and Null items.

A data type commonly used in networking that is not defined in this scheme is a datetime representation. To define such a data type, a string containing a date-time value in Internet type format is typically used.

4.1. JSON-B Examples

The following examples show examples of using JSON-B encoding:

```
A0 2A                           42 (as 8 bit integer)
A1 00 2A                        42 (as 16 bit integer)
A2 00 00 00 2A                  42 (as 32 bit integer)
A3 00 00 00 00 00 00 00 2A      42 (as 64 bit integer)
A5 00 01 42                     42 (as Bignum)

80 05 48 65 6c 6c 6f            "Hello" (single chunk)
81 00 05 48 65 6c 6c 6f         "Hello" (single chunk)
84 05 48 65 6c 6c 6f 80 00      "Hello" (as two chunks)

92 3f f0 00 00 00 00 00 00      1.0
92 40 24 00 00 00 00 00 00      10.0
92 40 09 21 fb 54 44 2e ea      3.14159265359
92 bf f0 00 00 00 00 00 00      -1.0

B0                              true
B1                              false
B2                              null
```

Figure 5

5. JSON-C

JSON-C (Compressed) permits numeric code values to be substituted for strings and binary data. Tag codes MAY be 8, 16 or 32 bits long encoded in network byte order.

Tag codes MUST be defined before they are referenced. A Tag code MAY be defined before the corresponding data or string value is used or at the same time that it is used.

A dictionary is a list of tag code definitions. An encoding MAY incorporate definitions from a dictionary using the dict-hash production. The dict hash production specifies a (positive) offset value to be added to the entries in the dictionary followed by the UDF fingerprint [draft-hallambaker-udf] of the dictionary to be used.

Production	Tag	Fixed	Length	Data Description
c-tag	xC0	1	-	8 bit tag code
c-tag	xC1	2	-	16 bit tag code
c-tag	xC2	4	-	32 bit tag code
c-def	xC4	1	-	8 bit tag definition
c-def	xC5	2	-	16 bit tag definition
c-def	xC6	4	-	32 bit tag definition
c-tag	xC8	1	-	8 bit tag code and definition
c-tag	xC9	2	-	16 bit tag code and definition
c-tag	xCA	4	-	32 bit tag code and definition
c-def	xCC	1	-	8 bit tag dictionary definition
c-def	xCD	2	-	16 bit tag dictionary definition
c-def	xCE	4	-	32 bit tag dictionary definition
dict-hash	xD0	4	1	UDF fingerprint of dictionary

Table 3

Table 3: Codes Used for Compression

All integer values are encoded in Network Byte Order (most significant byte first).

5.1. JSON-C Examples

The following examples show examples of using JSON-C encoding:

```
C8 20 80 05 48 65 6c 6c 6f       "Hello"    20 = "Hello"
C4 21 80 05 48 65 6c 6c 6f                  21 = "Hello"
C0 20                            "Hello"
C1 00 20                         "Hello"

D0 00 00 01 00 20             Insert dictionary at code 256
e3 b0 c4 42 98 fc 1c 14
9a fb f4 c8 99 6f b9 24
27 ae 41 e4 64 9b 93 4c
a4 95 99 1b 78 52 b8 55       UDF (C4 21 80 05 48 65 6c 6c 6f)
```

Figure 6

6. JSON-D (Data)

JSON-B and JSON-C only support the two numeric types defined in the JavaScript data model: Integers and 64 bit floating point values. JSON-D (Data) defines binary encodings for additional data types that are commonly used in scientific applications. These comprise positive and negative 128 bit integers, six additional floating point representations defined by IEEE 754 [IEEE754] and the Intel extended precision 80 bit floating point representation [INTEL] .

Should the need arise, even bigger bignums could be defined with the length specified as a 32 bit value permitting bignums of up to 2^35 bits to be represented.

```
d-value = d-integer | d-float

d-float = binary16 | binary32 | binary128 | binary80 |
decimal32 | decimal64 | decimal 128
```

Figure 7

The codes for these values are as follows:

Production	Tag	Fixed	Length	Data Description
p-int128	xA4	16	-	Positive 128 bit Integer
n-int128	xAC	16	-	Negative 128 bit Integer
binary16	x90	2	-	IEEE 754 Floating Point Binary 16 bit
binary32	x91	4	-	IEEE 754 Floating Point Binary 32 bit
binary128	x94	16	-	IEEE 754 Floating Point Binary 64 bit
Intel80	x95	10	-	Intel extended Floating Point 80 bit
decimal32	x96	4	-	IEEE 754 Floating Point Decimal 32
Decimal64	x97	8	-	IEEE 754 Floating Point Decimal 64
Decimal128	x98	16	-	IEEE 754 Floating Point Decimal 128

Table 4

Table 4: Additional Codes for Scientific Data

7. JBCD Frames and Records

Tag codes in the range xF0-XFF are reserved for specifying markers for frames and records. These tags are not used to encode JSON data, they are only used to encapsulate opaque binary data blobs as a unit.

A JBCD record consists of consist of the tag, a length and the data item. The length indication provided by the record format allows efficient traversal of a sequence of records in the forward direction only.

A JBCD Frames consists of consist of the tag, a length and the data item followed by the tag-length sequence repeated with the bytes written in the reverse order. The first length indication allows efficient traversal of a sequence of records in the forward direction and the second allows efficient traversal in the reverse direction.

[[This figure is not viewable in this format. The figure is available at http://mathmesh.com/Documents/draft-hallambaker-jsonbcd.html [3].]]

JBCD Records and Frames

The JBCD-Frame tags currently defined are:

Production	Tag	Fixed	Length	Data Description
uframe	xF0	-	1	Record, 8 bit length
uframe	xF1	-	2	Record, 16 bit length
uframe	xF2	-	4	Record, 32 bit length
uframe	xF3	-	8	Record, 64 bit length
bframe	xF4	-	1	Frame, 8 bit length
bframe	xF5	-	2	Frame, 16 bit length
bframe	xF6	-	4	Frame, 32 bit length
bframe	xF7	-	8	Frame, 64 bit length
	xF8-xFF	-	-	Reserved

Table 5

The author does not expect additional framing tags to be added but codes F8-FF are reserved in case this is desired.

It may prove convenient to represent message digest values as large integers rather than binary strings. While very few platforms or programming languages support mathematical operations on fixed size

integers larger than 64, this is not a major concern since message digests are rarely used for any purpose other than comparison for equality.

Production	Tag	Fixed	Length	Data Description
p-int128	Xa4	16	-	Positive 128 bit Integer
p-int256	Xa5	32	-	Positive 256 bit Integer
p-int512	Xa6	64	-	Positive 512 bit Integer

Table 6

8. Acknowledgements

This work was assisted by conversations with Nico Williams and other participants on the applications area mailing list.

9. Security Considerations

A correctly implemented data encoding mechanism should not introduce new security vulnerabilities. However, experience demonstrates that some data encoding approaches are more prone to introduce vulnerabilities when incorrectly implemented than others.

In particular, whenever variable length data formats are used, the possibility of a buffer overrun vulnerability is introduced. While best practice suggests that a coding language with native mechanisms for bounds checking is the best protection against such errors, such approaches are not always followed. While such vulnerabilities are most commonly seen in the design of decoders, it is possible for the same vulnerabilities to be exploited in encoders.

A common source of such errors is the case where nested length encodings are used. For example, a decoder relies on an outermost length encoding that specifies a length on 50 bytes to allocate memory for the entire result and then attempts to copy a string with a declared length of 1000 bytes within the sequence.

The extensions to the JSON encoding described in this document are designed to avoid such errors. Length encodings are only used to define the length of x-value constructions which are always terminal and cannot have nested data entries.

10. IANA Considerations

[TBS list out all the code points that require an IANA registration]

11. References

11.1. Normative References

[draft-hallambaker-udf]
Hallam-Baker, P., "Uniform Data Fingerprint (UDF)", draft-hallambaker-udf-09 (work in progress), April 2018.

[IEEE754] IEEE Computer Society, "IEEE Standard for Floating-Point Arithmetic", IEEE 754-2008, DOI 10.1109/IEEESTD.2008.4610935, August 2008.

[INTEL] Intel Corp., "Unknown".

[RFC7159] Bray, T., "The JavaScript Object Notation (JSON) Data Interchange Format", RFC 7159, DOI 10.17487/RFC7159, March 2014.

11.2. Informative References

[draft-hallambaker-mesh-architecture]
Hallam-Baker, P., "Mathematical Mesh: Architecture", draft-hallambaker-mesh-architecture-04 (work in progress), September 2017.

11.3. URIs

[1] http://mathmesh.com/Documents/draft-hallambaker-jsonbcd.html

[2] http://mathmesh.com/Documents/draft-hallambaker-jsonbcd.html

[3] http://mathmesh.com/Documents/draft-hallambaker-jsonbcd.html

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