MTAT.07.017
Applied Cryptography

Abstract Syntax Notation One (ASN.1)

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Abstract Syntax Notation One

"ASN.1 is a standard interface description language for defining data structures that can be serialized and deserialized in a cross-platform way. It is broadly used in telecommunications and computer networking, and especially in cryptography."

Notation to describe *abstract* types and values
Describes *information* – not representation

Similar to XML schema, however:

- ASN.1 is rich with built-in data types
- ASN.1 is not tied to particular encoding mechanism

ASN.1 example

```
-- ASN.1 module
MyQAProtocol DEFINITIONS ::= BEGIN
   MyQuestion ::= SEQUENCE {
      id INTEGER (0..999),
      text UTF8String
   }

   MyAnswer ::= SEQUENCE {
      id INTEGER (0..999),
      text UTF8String
   }
   -- new type defined
END
```

ASN.1 simple types

```
NULL -- only possible value is Null
BOOLEAN -- True or False
INTEGER -- whole numbers -infinity..+infinity
REAL -- mantissa, base, exponent
OCTET STRING -- values 0x00..0xFF
BIT STRING -- 0-s and 1-s
UTF8String -- UTF-8 characters
NumericString -- [space]0123456789
PrintableString -- printable ASCII chars
IA5String -- ASCII chars 0x00..0x7F
BMPString -- UNICODE BMP code points
UTCTime -- time in form "YYMMDDhhmmssZ"
```

There are more...

ASN.1 structured types

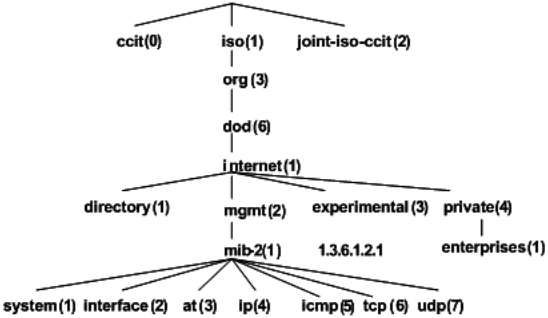
```
YearInfo ::= SEQUENCE {
    year        INTEGER (0..9999),
    isLeapYear BOOLEAN
}

Person ::= SET {
    name       IA5String,
    age        INTEGER,
    female     BOOLEAN
}

Prize ::= CHOICE {
    car         IA5String,
    cash        INTEGER,
    nothing     NULL
}
```

ASN.1 OBJECT IDENTIFIER

```
Algorithm  ::=  OBJECT IDENTIFIER
rsa  Algorithm ::=  {1.2.840.113549.1.1.1}
```

iso(1) member-body(2) us(840) rsadsi(113549) pkcs(1) pkcs-1(1) rsaEncryption(1)

OID tree:



`http://oid-info.com`

ASN.1 encodings

```
-- ASN.1 type definition
Question ::= SEQUENCE {
    id INTEGER,
    questionText UTF8String
}
```

How do we encode this structure for transmission?

The standard ASN.1 encoding rules:

- Basic Encoding Rules (BER)
- Distinguished Encoding Rules (DER)
- Packed Encoding Rules (PER)
- XML Encoding Rules (XER)
- JSON Encoding Rules (JER)

XML Encoding Rules (XER)

```
-- ASN.1 type definition
Question ::= SEQUENCE {
    id INTEGER,
    questionText UTF8String
}

<!-- XER-encoded object -->
<Question>
  <id>42</id>
  <questionText>Why is it so?</questionText>
</Question>
```

- Human readable
- Inefficient encoding
- Canonicalization needed

Distinguished Encoding Rules (DER)

- Efficient encoding
- A value can be encoded only in a single way
- Data is encoded as type-length-value (TLV) element:

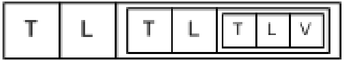
```
message UTF8String :: = "Hello"
```

Type: UTF8String
Length: 5 bytes
Value: "Hello"

DER encoded:

```
[0x0c] [0x05] [0x48 0x65 0x6c 0x6c 0x6f] ...
```

```
$ echo -e -n "\x0c\x05Hello" > hello.der
$ sudo apt install dumpasn1
$ dumpasn1 hello.der
  0   5: UTF8String 'Hello'
```



Task: ASN.1 DER encoder – 10p

Implement ASN.1 DER encoder that can encode subset of ASN.1 types by implementing these functions:

```
def asn1_boolean(bool):
def asn1_integer(i):
def asn1_bitstring(bitstr):
def asn1_octetstring(octets):
def asn1_null():
def asn1_objectidentifier(oid):
def asn1_sequence(der):
def asn1_set(der):
def asn1_printablestring(string):
def asn1_utctime(time):
def asn1_tag_explicit(der, tag):
def asn1_len(content): <-- helper function
```

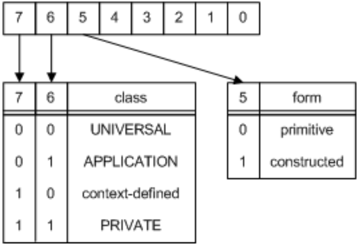
Task: ASN.1 DER encoder

And encodes this artificial ASN.1 structure (test case):

NB! `dumpasn1` fails to decode negative integers and outputs bitstrings in reverse order.

```
$ dumpasn1 asn1.der
  0 114: [0] {    explicit tags
  2 112:   SEQUENCE {
  4  16:     SET {
  6   1:       INTEGER 5
  9   4:       [2] {
 11   2:         INTEGER 200
       :         }
 15   5:       [11] {
 17   3:         INTEGER 65407
       :         }
       :       }
 22   1:     BOOLEAN TRUE
 25   2:     BIT STRING 5 unused bits
       :       '011'B
       :       Error: Spurious zero bits in bitstring.
 29  51:     OCTET STRING
       :       00 01 02 02 02 02 02 02 02 02 02 02 02 02 02 02
       :       02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02
       :       02 02 02 02 02 02 02 02 02 02 02 02 02 02 02 02
       :       02 02 02
 82   0:     NULL
 84   7:     OBJECT IDENTIFIER '1 2 840 113549 1'
 93   6:     PrintableString 'hello.'
101  13:     UTCTime 23/02/2015 01:09:00 GMT
       :     }
       :   }
0 warnings, 1 error.
asn1_tag_explicit(asn1_sequence(asn1_set(...)+asn1_boolean(true)+...), 0)

$ ./asn1_encoder.py asn1.der
```

Type-Length-Value: Type




```
Universal tags (Bits 4,3,2,1,0):
00001 (1) - BOOLEAN
00010 (2) - INTEGER
00011 (3) - BIT STRING
00100 (4) - OCTET STRING
00101 (5) - NULL
00110 (6) - OBJECT IDENTIFIER
01010 (10) - ENUMERATED
01100 (12) - UTF8String
10000 (16) - SEQUENCE
10001 (17) - SET
10011 (19) - PrintableString
10111 (23) - UTCTime
...
```

0x0c – 00 0 01100 (universal, primitive, UTF8String)

A Layman's Guide to a Subset of ASN.1, BER, and DER:

`http://luca.ntop.org/Teaching/Appunti/asn1.html`

ASN.1 encoding rules: Specification of BER, CER and DER:

`http://www.itu.int/ITU-T/studygroups/com17/languages/X.690-0207.pdf`

Type-Length-Value: Length

- `asn1_len(value_bytes)`: – 1.5p
  - If the number of value bytes $<$ 128 then length byte encodes the number of bytes in the value
  - Else the most significant bit of the first length byte is set to 1 and the remaining 7 bits encode the number of length bytes that follow
    - The following length bytes encode the number of value bytes (use `nb()` without the `length` parameter)

Example:

```
Length 126:  01111110
Length 127:  01111111
Length 128:  10000001 10000000
Length 1027: 10000010 00000100 00000011
                      (4 << 8) | 3
                           = 1027
```

ASN.1 DER encoding

- `asn1_boolean(bool):` – 0p
  - Encodes boolean value
  - Universal, primitive, tag 1 (00 0 00001)
  - Value byte contains `0x00` for `FALSE` and `0xff` for `TRUE`
- `asn1_integer(int):` – 1p
  - Encodes integer (only positive integers must be supported)
  - Universal, primitive, tag 2
  - Two's complement integer encoding:
    - Convert integer to bytestring using `nb()` without the `length` parameter
    - Integer value 0 is encoded as zero byte (not empty bytestring)
    - If the most significant bit of MSB for a positive integer is 1 then prepend zero (`0x00`) byte

```
INTEGER: 140
DER: 00000010  00000010   00000000   10001100
          Type      Length    Padding    Integer
```

250,000 Estonian ID cards could be faulty

https://news.err.ee/116849/250-000-estonian-id-cards-could-be-faulty

A **coding mistake by the Certification Center**, the company behind the software of ID cards, means 250,000 ID cards could cause problems for users in the future.

The problem concerns Estonian ID cards issued between September 2014 and September 2015, and if not fixed, will mean users are unable to use ID cards with the new version of the Google Chrome browser.

"We let a fault slip through our software development process," Certification Center head Kalev Pihl told Postimees. The problem surfaced when Google worked out a **new version of Chrome, which has more detailed checks**.

ASN.1 DER encoding

- `asn1_bitstring(str_of_bits)`: – 2p
  - Encodes an arbitrary bitstring value (e.g. '010101')
  - Universal, primitive, tag 3
  - Bitstring is right-padded with zero bits to form full byte string
  - First byte of value bytes encodes number of padding bits

```
BIT STRING: 010101
DER: 00000011  00000010     00000010     01010100
       Type      Length   Padding-length Padded-bitstring
```

- `asn1_octetstring(bytes)`: – 0.2p
  - Encodes an arbitrary string of octets
  - Universal, primitive, tag 4
- `asn1_null()`: – 0.2p
  - Denotes a null value
  - Universal, primitive, tag 5
  - No value bytes

ASN.1 DER encoding

- `asn1_objectidentifier(list_of_oid_components)`: – 3p
  - An object identifier, which is a sequence of integer components
  - Universal, primitive, tag 6
  - The first value byte has value: `40 * comp1 + comp2`
  - The following value bytes encode `comp3, comp4, ...`
    - Each component is encoded using 7 righmost bits of the bytes
    - Each byte's leftmost bit (except for the last) is 1

Example:

```
OBJECT IDENTIFIER: 1.2.840 (US (ANSII))
0000 0110  0000 0011     0010 1010    1 0000110     0 1001000
 Type        Length        40*1+2          6              72
                                       (6 << 7) | 72 = 840
```

- `asn1_sequence(der_bytes)`: – 0.2p
  - Encodes ordered collection of one or more types
  - Universal, **constructed**, tag 16
  - Value bytes contain DER encoded data

ASN.1 DER encoding

- `asn1_set(der_bytes)`: – 0.2p
  - Encodes unordered collection of one or more types
  - Universal, **constructed**, tag 17
  - Value bytes contain DER encoded data
- `asn1_printablestring(bytes)`: – 0.2p
  - Encodes an arbitrary string of printable characters `[a-zA-Z0-9' ()+,-./:=?]`
  - Universal, primitive, tag 19
  - Value bytes contain printable string characters
- `asn1_utctime(date_str)`: – 0.2p
  - Encodes "coordinated universal time" (GMT – Greenwich Mean Time)
  - Universal, primitive, tag 23
  - Value bytes contain string representation of time in form "YYMMDDhhmmssZ"

ASN.1 Tagging

ASN.1 notation may be ambiguous:

```
Ambiguous ::= SEQUENCE {
  val1 INTEGER OPTIONAL,
  val2 INTEGER OPTIONAL
}
```

Unable to decode if encoded structure contains only one value!

Fix is to tag the values:

```
unambiguous ::= SEQUENCE {
  val1 [1] IMPLICIT INTEGER OPTIONAL,
  val2 [2] EXPLICIT INTEGER OPTIONAL
}
```

- IMPLICIT overwrites the existing type byte of TLV
- EXPLICIT prepends type and length bytes (encapsulates original TLV)

http://powerasn.ncottin.net/download/ASN1_Tagging.pdf

ASN.1 DER encoding

- `asn1_tag_explicit(der, tag)`:
  - Tags/encapsulates any data type
  - **Context-defined, constructed**, tag n (5 rightmost bits)
    - No need to implement support for tag > 30
  - Value bytes contain DER-encoded data

```
>>> asn1 = asn1_tag_explicit(asn1_sequence(asn1_null()), 5)
>>> open('asn1', 'wb').write(asn1)
```

```
$ dumpasn1 asn1
  0   4: [5] {
  2   2:   SEQUENCE {
  4   0:     NULL
       :     }
       :   }
```

Banned functions

Your solution should **not** use:

- functions: `bin()`, `int()`, `hex()`, `str()`, `bytearray()`, `divmod()`
- exponentiation: `**`, `pow()`
- division and modulus: `/`, `%` (unless needed for computing bitstring padding size)

Use bitwise operations as much as possible!

For example, to convert `str` containing bit representation to `int`:

```
i = 0
for bit in '010001':
    i<<=1
    if bit=='1':
        i|= 1
```

As a general rule for all homeworks: encoding values to "bin" and "hex" representation is allowed only for printing out non-printable binary data.