# Network VPI Library

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## Abstract

This document addresses VPI (Verilog Programming Interface) library for network applications, which include Ethernet, IP, UDP, TCP and PTPv2.

## Table of contents

# 1 Introduction

Network VPI Library is a collection of VPI (Verilog Programming Interface) tasks that handles network packets, which include Ethernet, IP, UDP, TCP and PTPv2.

VPI enables HDL (Hardware Description Language) simulator to invoke C routines.

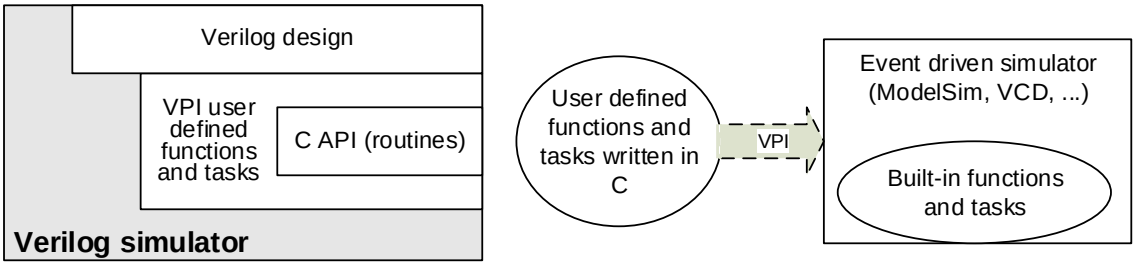



**Figure 1: VPI interface**

# 2 Quick start

```
module top;
... ...
reg [ 7:0] pkt_eth[0:4095];
   reg [47:0] mac_src;
   reg [47:0] mac_dst;
   reg [15:0] type_len;
   reg [15:0] bnum_payload;
   reg [ 7:0] payload[0:4095];
   reg [15:0] bnum_pkt;
   integer add_crc;
   integer add_preamble;
   integer idx;
   initial begin
        for (idx=0; idx<4096; idx=idx+1) pkt_eth[idx] = 8'hFF;
        mac_src=48'h02_12_34_56_78_9A;
        mac_dst=48'h02_11_22_33_44_55;
        for (idx=0; idx<4096; idx=idx+1) payload[idx] = idx;
        type_len=0; // 0 means to use 'bnum_payload'
        bnum_payload = 10;
        type_len = bnum_payload;
        add_crc = 0;
        add_preamble = 0;
        bnum_pkt=0
        // this task fills Ethernet packet in the ‘pkt_eth'
        // that contains 'bnum_pkt' bytes.
        $pkt_ethernet(pkt_eth
                ,bnum_pkt
                ,mac_src
```

```
                ,mac_dst
                ,type_len
                ,bnum_payload
                ,payload
                ,add_crc
                ,add_preamble
                );
    end
... ...
endmodule
```

Following shows an example ‘Makefile’ to compile and simulate the above code, where ModelSim is used for HDL simulator.

```
all: vlib vlog vsim

vlib:
    if [ -f compile.log ]; then /bin/rm -f compile.log; fi
    if [ -d work ]; then /bin/rm -rf work; fi
    vlib work 2>&1 | tee -a compile.log

vlog:
    vlog -work work top.v 2>&1 | tee -a compile.log

vsim:
    vsim -pli …../network_vpi.dll -novopt -c -do "run -all; quit" -lib work work.top
```

# 3 Building library

## 3.1 Directory

| directory | | | remarks |
|---|---|---|---|
| doc | | | document |
| vpi | | | VPI sources |
| | src | | |
| vpi_llib | | | by product from ‘vpi’ |
| | modelsim/10.3 | | |
| | | linux_x86_64/libnetwork_vpi.so | Linux 64-bit (GCC) |
| | | mingw_x86_64/network_vpi.dll | MinGW 64-bit (GCC) |
| | | MS64/network_vpi.dll | Visual Studio 64-bit |
| | | MS32/network_vpi.dll | Visual Studio 32-bit |
| vpi_test | | | Testing |

## 3.2 Building library

Figure 2 shows a flow to prepare VPI library, where ‘VPI routines header file’ and ‘System’s VPI library’ are simulator dependent.

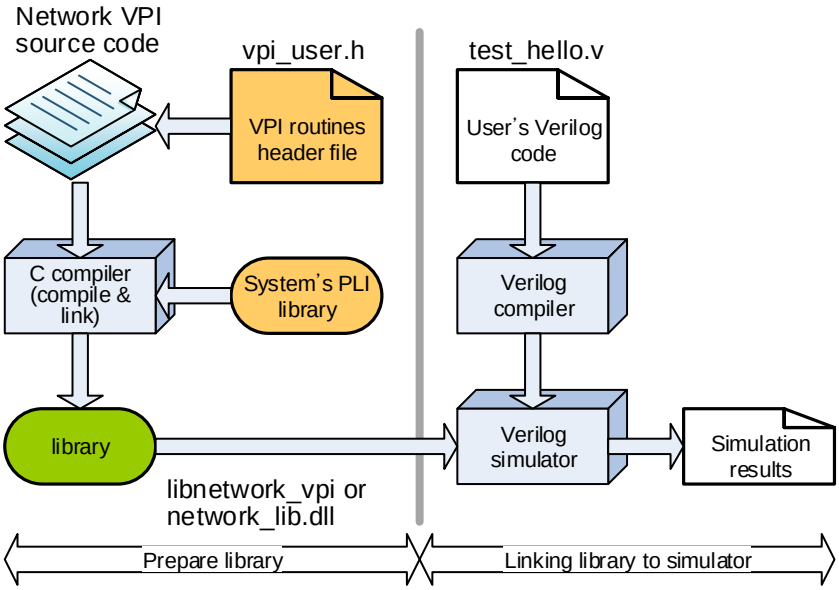



**Figure 2: General flow to prepare VPI library**

### 3.2.1 Linux or MinGW case

Simply go to 'vpi' directory and run 'make clean; make; make install'. Then, following dynamically linkable shared library will be ready in 'vpi_lib' directory.

```
$ cd vpi
$ make clean
$ make
$ make install
```

- For Linux 64-bit
  - vpi_lib/modelsim/10.3/linux_x86_64/libnetwork_vpi.so
- For MinGW 64-bit
  - vpi_lib/modelsim/10.3/linux_x86_64/network_vpi.dll

Where '10.3' indicates version of ModelSim.

### 3.2.2 Visual Studio case

Simply go to 'vpi' directory and do as described below. Then, following dynamically linkable shared library will be ready in 'vpi_lib' directory.

```
Open CMD window
WIN_RUN.bat
nmake –f NMAKEFILE clean
nmake –f NMAKEFILE
nmake –f
```

- For Visual Studio 64-bit
  - vpi_lib/modelsim/10.3/MS64/network_vpi.dll
- For Visual Studio 32-bit
  - vpi_lib/modelsim/10.3/MS32/network_vpi.dll

Where ’10.3’ indicates version of ModelSim.

# 4 VPI tasks

## 4.1 Ethernet packet handling tasks

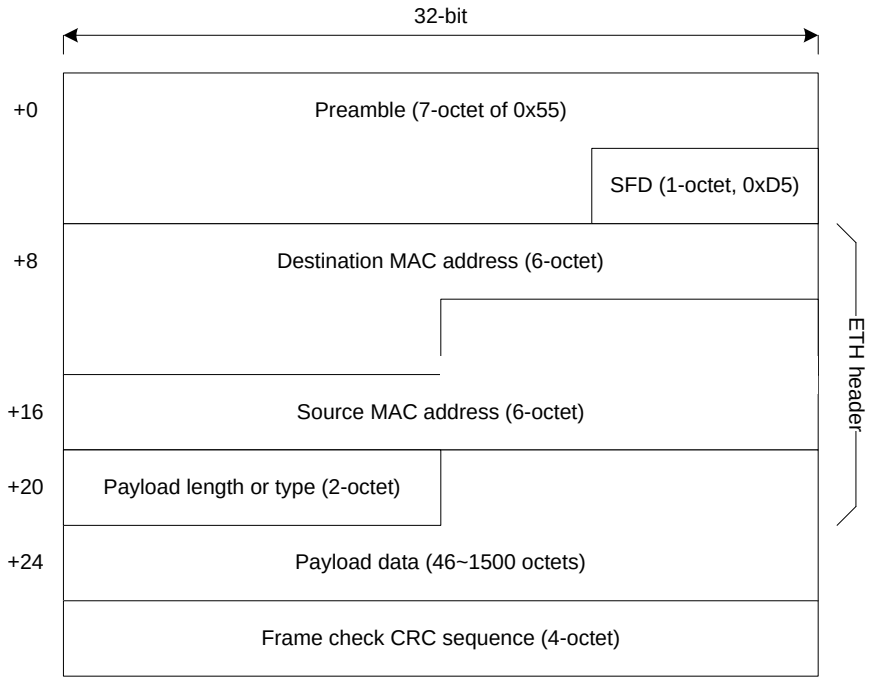
### 4.1.1 $pkt_ethernet()

```
$pkt_ethernet( pkt[7:0][0:4095]   // output
        , bnum_pkt[15:0] // output
        , mac_src [47:0] // input
        , mac_dst [47:0] // input
        , type_len[15:0] // input
        , bnum_payload[15:0] // input
        , payload[7:0][0:4095] // input
        , add_crc // input
        , add_preamble // input
        );
```

‘$pkt_ethernet()’ builds Ethernet packet in the ‘pkt’ argument, which is 8-bit 4096-entry register.

- pkt[7:0][0:4095]: register argument where Ethernet packet is filled; it is 8-bit width and can be up 4096 entries.
- bnum_pkt[15:0]: num of bytes of the whole packet that has been built by this task, i.e., the number of bytes in the ‘pkt[...][...]’.
- mac_src[47:0]: 48-bit Ethernet physical address for source, where [47:40] is MSByte
- mac_dst[47:0]: 48-bit Ethernet physical address for destination
- type_len[15:0]: 16-bit type-length value of Ethernet packet, use ‘bnum_payload[..]’ when it is zero.
- bnum_payload[15:0]: num of bytes of in the ‘payload[...][...]’ argument.
- payload[7:0][0:4095]: register argument where Ethernet payload is given
- add_crc: add CRC at the end of the packet, if it is 1.
- add_preamble : add preamble[1] at the beginning of ‘pkt[...][...]’, if it is 1.

[1] 0x55/0x55/0x55/0x55/0x55/0x55/0x55/0xD5




### 4.1.2 $pkt_ethernet_parser()

```
$pkt_ethernet_parser( pkt[ 7:0][0:4095] // input
                    , bnum_pkt[15:0] // input
                    , crc // input
                    , preamble // input
                    );
```

'$pkt_ethernet_parser()' prints contents of 'pkt[...][...]' by interpreting it as Ethernet packet.

- ✧ pkt[7:0][0:4095]: register argument where Ethernet packet resides; it is 8-bit width and can be up 4096 entries.
- ✧ bnum_pkt[15:0]: the number of bytes in the 'pkt[...][...]'.
- ✧ crc: the packet contains CRC, if it is 1.
- ✧ preamble: the packet contains preamble, if it is 1.

## 4.2 IP packet handling tasks

### 4.2.1 $pkt_ip()

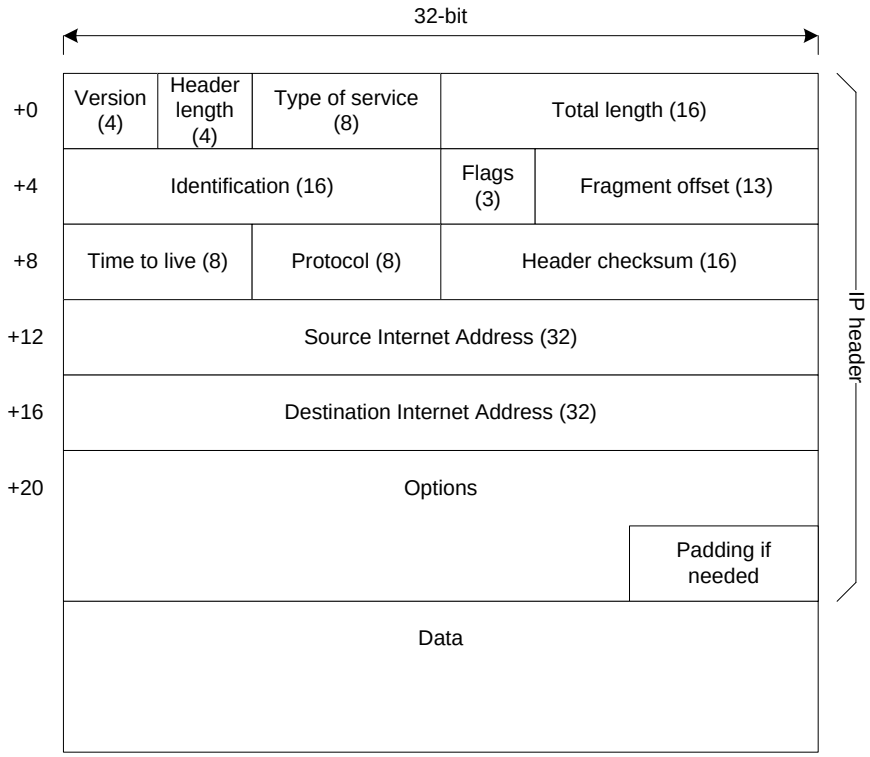
```
$pkt_ip( pkt[7:0][0:4095] // output
      , bnum_pkt[15:0] // output
      , ip_src[31:0] // input
      , ip_dst[31:0] // input
      , protocol[7:0] // input
```

```
    , ttl[7:0] // input
    , bnum_payload[15:0] // input
    , payload[7:0][0:4095] // input
    , tcp_check // input
    );
```

‘$pkt_ip()’ builds IPv4 packet in the ‘pkt’ argument, which is 8-bit 4096-entry register.

- pkt[7:0][0:4095]: register argument where IP packet is filled; it is 8-bit width and can be up 4096 entries.
- bnum_pkt[15:0]: num of bytes of the whole packet that has been built by this task, i.e., the number of bytes in the ‘pkt[...][...]’.
- ip_src[31:0]: 31-bit IPv4 address for source, where [31:24] is MSByte
- ip_dst[31:0]: 31-bit IPv4 address for destination
- protocol[7:0]: 8-bit protocol value of the packet
- ttl[7:0]: 8-bit Time-To-Live value of the packet
- bnum_payload[15:0]: num of bytes of in the ‘payload[...][...]’ argument.
- payload[7:0][0:4095]: register argument where IP payload is given
- tcp_check: update TCP header check sum when it is 1 and ‘protocol’ is 0x06.

It fills other fields including ‘Version’, ‘Header Length’, ‘Header Checksum’, and so on.



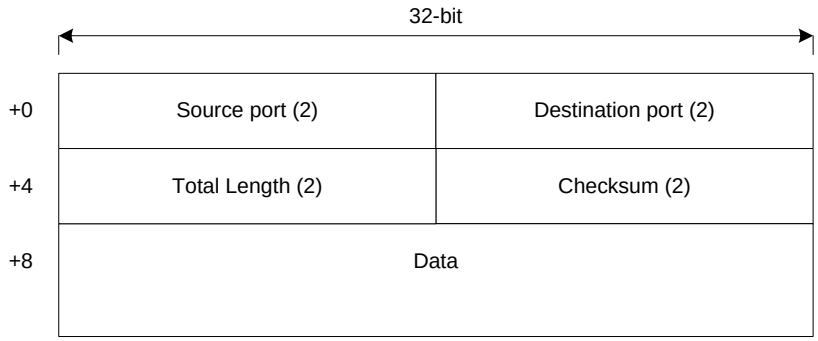

## 4.3 UDP packet handling tasks

### 4.3.1 $pkt_udp()

```
$pkt_udp( pkt[7:0][0:4095] // output
        , bnum_pkt[15:0] // output
        , port_src[15:0] // input
        , port_dst[15:0] // input
        , bnum_payload[15:0] // input
        , payload[7:0][0:4095] // input
        );
```

'$pkt_udp()' builds UDP packet in the 'pkt' argument, which is 8-bit 4096-entry register.

- ✧ pkt[7:0][0:4095]: register argument where UDP packet is filled; it is 8-bit width and can be up 4096 entries.
- ✧ bnum_pkt[15:0]: num of bytes of the whole packet that has been built by this task, i.e., the number of bytes in the 'pkt[...][...]'.
- ✧ port_src[31:0]: 31-bit port for source, where [31:24] is MSByte
- ✧ port_dst[31:0]: 31-bit port for destination
- ✧ bnum_payload[15:0]: num of bytes of in the 'payload[...][...]' argument.
- ✧ payload[7:0][0:4095]: register argument where UDP payload is given




### 4.3.2 $pkt_udp_ip_ethernet()

```
$pkt_udp_ip_ethernet( pkt     [7:0][0:4095] // output
        , bnum_pkt[15:0] // output, num of bytes of the whole packet
        , port_src[15:0]
        , port_dst[15:0]
        , ip_src  [31:0]
        , ip_dst  [31:0]
        , ttl     [ 7:0]
        , mac_src [47:0]
        , mac_dst [47:0]
        , bnum_payload[15:0] // num of bytes of payload
        , payload [7:0][0:4095]
        , add_crc      //
        , add_preamble //
```

```
    );
```

‘$pkt_udp_ip_ethernet()’ builds UDP/IP/Ethernet packet in the ‘pkt’ argument, which is 8-bit 4096-entry register.

- pkt[7:0][0:4095]: register argument where UDP/IP/Ethernet packet is filled; it is 8-bit width and can be up 4096 entries.
- bnum_pkt[15:0]: num of bytes of the whole packet that has been built by this task, i.e., the number of bytes in the ‘pkt[...][...]’.
- port_src[31:0]: 31-bit  port for source, where [31:24] is MSByte
- port_dst[31:0]: 31-bit port for destination
- ip_src[31:0]: 31-bit IPv4 address for source, where [31:24] is MSByte
- ip_dst[31:0]: 31-bit IPv4 address for destination
- ttl[7:0]: 8-bit Time-To-Live value of the packet
- bnum_payload[15:0]: num of bytes of in the ‘payload[...][...]’ argument.
- payload[7:0][0:4095]: register argument where IP payload is given
- mac_src[47:0]: 48-bit Ethernet physical address for source, where [47:40] is MSByte
- mac_dst[47:0]: 48-bit Ethernet physical address for destination
- bnum_payload[15:0]: num of bytes of in the ‘payload[...][...]’ argument.
- payload[7:0][0:4095]: register argument where UDP payload is given

‘protocol[7:0]’ field of IP will be 0x11 (UDP), and ‘type_len[15:0]’ field of Ethernet will be 0x0800

## 4.4 TCP packet handling tasks

### 4.4.1 $pkt_tcp()

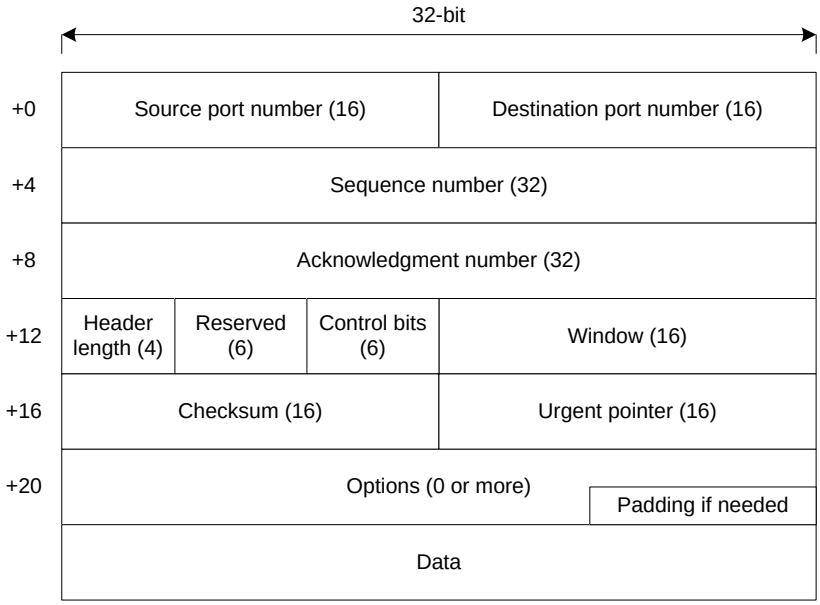
```
$pkt_tcp( pkt[7:0][0:4095] // output
        , bnum_pkt[15:0] // output
        , port_src[15:0] // input
        , port_dst[15:0] // input
        , seq_num[31:0] // input
        , ack_num[31:0] // input
        , bnum_payload[15:0] // input
        , payload[7:0][0:4095] // input
);
```

‘$pkt_tcp()’ builds TCP packet in the ‘pkt’ argument, which is 8-bit 4096-entry register.

- pkt[7:0][0:4095]: register argument where TCP packet is filled; it is 8-bit width and can be up 4096 entries.
- bnum_pkt[15:0]: num of bytes of the whole packet that has been built by this task, i.e., the number of bytes in the ‘pkt[...][...]’.
- port_src[31:0]: 31-bit  port for source, where [31:24] is MSByte
- port_dst[31:0]: 31-bit port for destination

- ✧ seq_num[31 :0] :
- ✧ ack_num[31 :0] :
- ✧ bnum_payload[15:0]: num of bytes of in the ‘payload[...][...]’ argument.
- ✧ payload[7:0][0:4095]: register argument where UDP payload is given

It fills ‘Checksum’ with 0, since pseudo header is not available; ‘Checksum’ can be updated when it is merged in IP packet.




## 4.5 PTPv2 packet handling tasks

### 4.5.1 $msg_ptpv2_set_context()

```
$msg_ptpv2_set_context( ptp_version // input
                      , ptp_domain // input
                      , one_step_clock // input
                      , unicast_port // input
                      , profile_spec1 // input
                      , profile_spec2 // input
                      );
```

‘$msg_ptpv2_set_context()’ fills PTPv2 context data structure, which is required to build PTPv2 message.

- ✧ ptp_version: it should be 2 for PTPv2
- ✧ ptp_domain:
- ✧ one_step_clock: 1 means one-step[2] clock, 0 means two-step clock
- ✧ unicast_port

[2] ‘Sync’ message carries time-stamp; It does not require ‘Follow_Up’ message aftward.

- ✧ profile_spec1
- ✧ profile_spec2

#### 4.5.2 $msg_ptpv2_get_context()

```
$msg_ptpv2_get_context( ptp_version // output
                      , ptp_domain // output
                      , one_step_clock // output
                      , unicast_port // output
                      , profile_spec1 // output
                      , profile_spec2  // output
                      );
```

'$msg_ptpv2_get_context()' geturns PTPv2 context information, which is required to build PTPv2 message.

- ✧ ptp_version: it should be 2 for PTPv2
- ✧ ptp_domain:
- ✧ one_step_clock: 1 means one-step[3] clock, 0 means two-step clock
- ✧ unicast_port
- ✧ profile_spec1
- ✧ profile_spec2

#### 4.5.3 $msg_ptpv2()

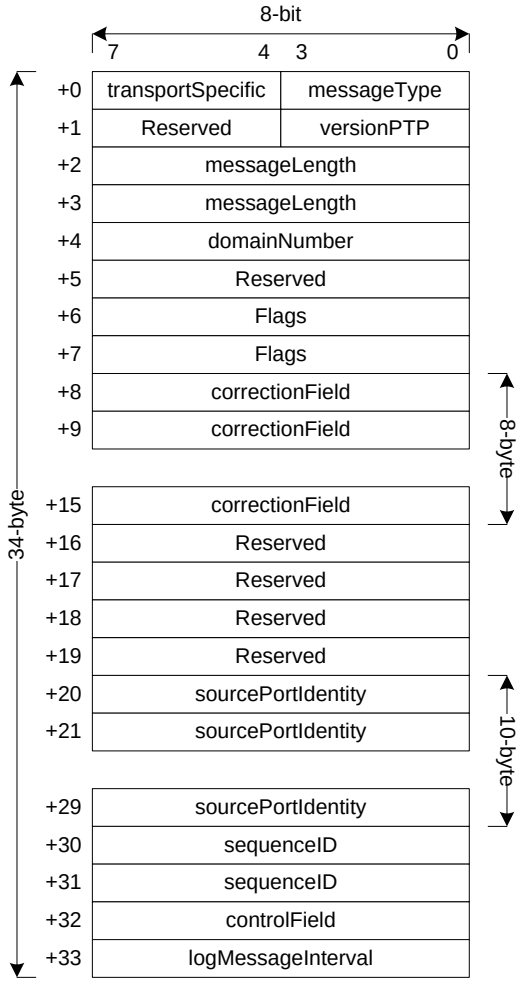
```
$$msg_ptpv2( pkt[7:0][0:4095] // output
           , bnum_pkt[15:0] // output
           , messageType[3:0] // input
           , secondsField[47:0] // input
           , nanosecondsField[31:0] // input
           , sequenceID[15:0] // input
           , sourcePortIdentity[79:0] // input
           , correctionField[63:0] // input
           , flagField[15:0] // input
           );
```

'$msg_ptpv2()' builds PTPv2 message in the 'pkt' argument, which is 8-bit 4096-entry register.

- ✧ pkt[7:0][0:4095]: register argument where PTPv2 message is filled; it is 8-bit width and can be up 4096 entries.
- ✧ bnum_pkt[15:0]: num of bytes of the whole packet that has been built by this task, i.e., the number of bytes in the 'pkt[...][...]'.
- ✧ messageType[3:0]: 4-bit message type
- ✧ secondsField[47:0]: second value
- ✧ nanosecondsField[31:0]: nano-second value

[3] 'Sync' message carries time-stamp; It does not require 'Follow_Up' message aftward.

- ✧ sequenceID[15:0]: sequence identification
- ✧ sourcePortIdentiry[79:0]: 10-byte identity
  - 3-byte OUI
  - 5-byte UUID
  - 2-byte PTP node port number
- ✧ correctionField[63:0]: 8-byte
- ✧ flagField[15:0]: 2-byte
  - flagField[9]: twoStepFlag when 1
  - flagField[10]: unicastFlag when 1




### 4.5.4 $msg_ptpv2_etherent()

```
$msg_ptpv2_ethernet ( pkt[7:0][0:4095] // output
                    , bnum_pkt[15:0] // output
                    , mac_src[47 :0] // input
                    , messageType[3:0] // input
                    , flagField[15 :0] // input
                    , correctionField[63 :0] // input
                    , sourceClockID[63 :0] // input
```

```
                , sourcePortID[15:0] // input
                , sequenceID[15:0] // input
                , secondsField[47:0] // input
                , nanosecondsField[31:0] // input
                , sequenceID[15:0] // input
                , sourcePortIdentity[79:0] // input
                , reqClockID[63 :0] // input
                , reqPortID[15:0] // input
                , add_crc // input
                , add_preamble // input
                );
```

'$msg_ptpv2_ethernet()' builds PTPv2 message over Ethernet packet in the 'pkt' argument, which is 8-bit 4096-entry register.

- ✧ pkt[7:0][0:4095]: register argument where PTPv2 message over raw Ethernet packet is filled; it is 8-bit width and can be up 4096 entries.
- ✧ bnum_pkt[15:0]: num of bytes of the whole packet that has been built by this task, i.e., the number of bytes in the 'pkt[...][...]'.
- ✧ mac_src[47:0]: 48-bit Ethernet physical address for source, where [47:40] is MSByte
- ✧ messageType[3:0]: 4-bit message type
- ✧ flagField[15:0]: 2-byte
  - flagField[9]: twoStepFlag when 1
  - flagField[10]: unicastFlag when 1
- ✧ correctionField[63:0]: 8-byte
- ✧ sourceClockID[63:0]: 8-byte
  - 3-byte OUI
  - 5-byte UUID
- ✧ sourcePortIdentiry[15:0]: 2-byte identity
  - 2-byte PTP node port number
- ✧ sequenceID[15:0]: sequence identification
- ✧ secondsField[47:0]: second value
- ✧ nanosecondsField[31:0]: nano-second value
- ✧ reqClockID[63:0]: 8-byte
- ✧ reqPortIdentiry[15:0]: 2-byte identity
- ✧ add_crc: add CRC at the end of the packet, if it is 1.
- ✧ add_preamble : add preamble (i.e., 0x55/0x55/0x55/0x55/0x55/0x55/0x55/0xD5) at the beginning of 'pkt[...][...]', if it is 1.

#### 4.5.5 $msg_ptpv2_udp_ip_ethernet()

```
$msg_ptpv2_udp_ip_ethernet ( pkt[7:0][0:4095] // output
                , bnum_pkt[15:0] // output
                , mac_src[47 :0] // input
                , ip_adr[31:0] // input
                , messageType[3:0] // input
                , flagField[15 :0] // input
```

```
                , correctionField[63 :0] // input
                , sourceClockID[63 :0] // input
                , sourcePortID[15:0] // input
                , sequenceID[15:0] // input
                , secondsField[47:0] // input
                , nanosecondsField[31:0] // input
                , sequenceID[15:0] // input
                , sourcePortIdentity[79:0] // input
                , reqClockID[63 :0] // input
                , reqPortID[15:0] // input
                , add_crc // input
                , add_preamble // input
                );
```

'$msg_ptpv2_ethernet()' builds PTPv2 message over UDP/IP/Ethernet packet in the 'pkt' argument, which is 8-bit 4096-entry register.

- pkt[7:0][0:4095]: register argument where PTPv2 message over raw Ethernet packet is filled; it is 8-bit width and can be up 4096 entries.
- bnum_pkt[15:0]: num of bytes of the whole packet that has been built by this task, i.e., the number of bytes in the 'pkt[...][...]'.
- mac_src[47:0]: 48-bit Ethernet physical address for source, where [47:40] is MSByte
- ip_addr[31:0]: 32-bit IP address
- messageType[3:0]: 4-bit message type
- flagField[15:0]: 2-byte
  - flagField[9]: twoStepFlag when 1
  - flagField[10]: unicastFlag when 1
- correctionField[63:0]: 8-byte
- sourceClockID[63:0]: 8-byte
  - 3-byte OUI
  - 5-byte UUID
- sourcePortIdentiry[15:0]: 2-byte identity
  - 2-byte PTP node port number
- sequenceID[15:0]: sequence identification
- secondsField[47:0]: second value
- nanosecondsField[31:0]: nano-second value
- reqClockID[63:0]: 8-byte
- reqPortIdentiry[15:0]: 2-byte identity
- add_crc: add CRC at the end of the packet, if it is 1.
- add_preamble : add preamble (i.e., 0x55/0x55/0x55/0x55/0x55/0x55/0x55/0xD5) at the beginning of 'pkt[...][...]', if it is 1.

# 5 C API

## 5.1 CRC and checksum related API

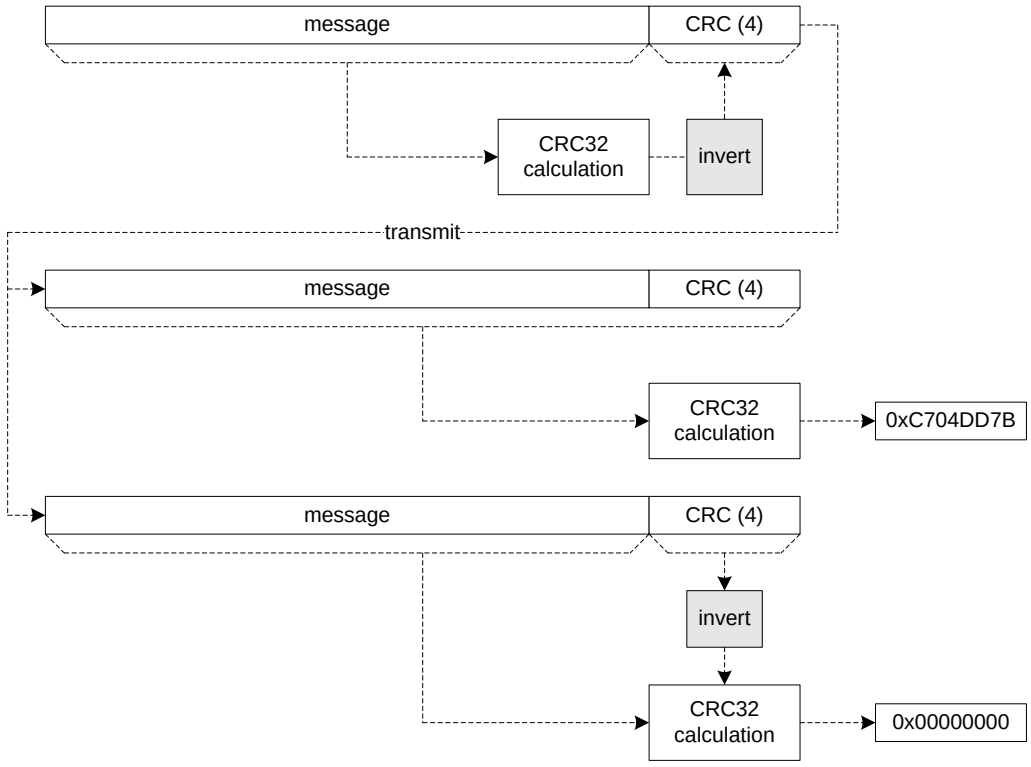
### 5.1.1 compute_eth_crc ()

```
#include "eth_ip_udp_tcp_pkt.h"
uint32_t compute_eth_crc(uint8_t *message // data buffer
                         , int len) ; // data length in bytes
```

'compute_eth_crc()' calculates Ethernet CRC and returns the result after inversion.

It uses following polynomial.
$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$
*(0x1_04C1_1DB7; 0xEDB8_8320/reverse[4])*

Residue of G(x) is as folow.
$S(x)=x^{31}+x^{30}+x^{26}+x^{25}+x^{24}+x^{18}+x^{15}+x^{14}+x^{12}+x^{11}+x^{10}+x^8+x^6+x^5+x^4+x^3+x+1$
= 0xC704_DD7B (0xDEBB_20E3/reverse)




### 5.1.2 compute_checksum ()

```
#include "eth_ip_udp_tcp_pkt.h"
uint32_t compute_checksum(uint8_t *pkt, int bnum);
```

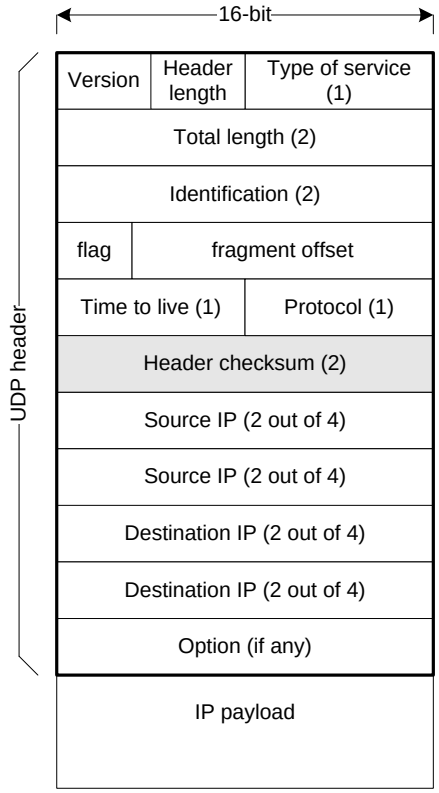
[4] When the first bit is corresponds $X^{31}$, 0x04C_1DB& will be used.

‘compute_checksum()’ calculates checksum and returns the result without inversion

### 5.1.3 compute_ip_checksum ()

```
#include "eth_ip_udp_tcp_pkt.h"
uint32_t compute_ip_checksum(ip_hdr_t *iphdr) ;
```

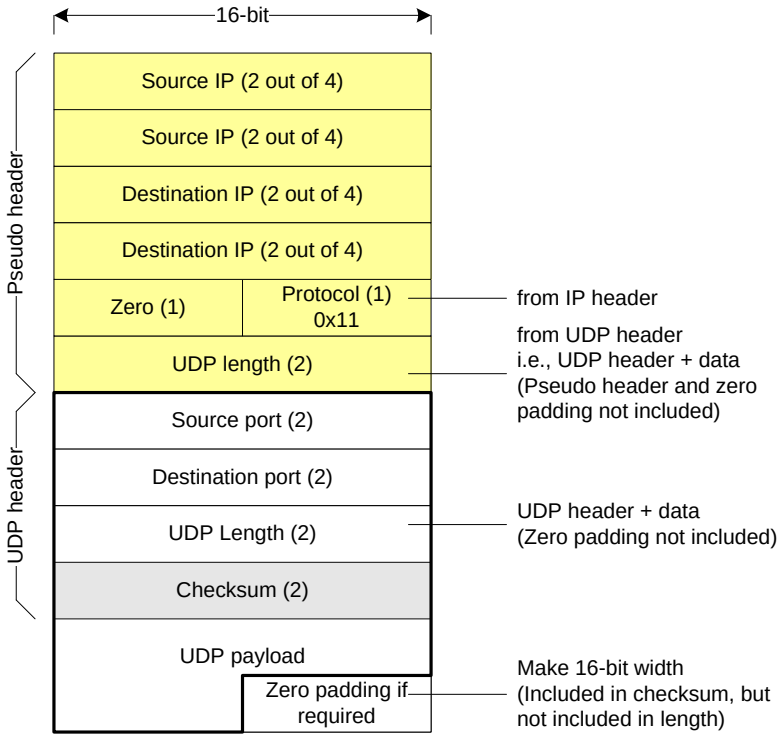
‘compute_ip_checksum()’ calculates checksum of IP header and returns the result after inversion.




### 5.1.4 compute_udp_checksum ()

```
#include "eth_ip_udp_tcp_pkt.h"
uint32_t compute_udp_checksum(pseudo_ip_hdr *ip_hdr
                                    , upd_hdr_t *udp_hdr) ;
```

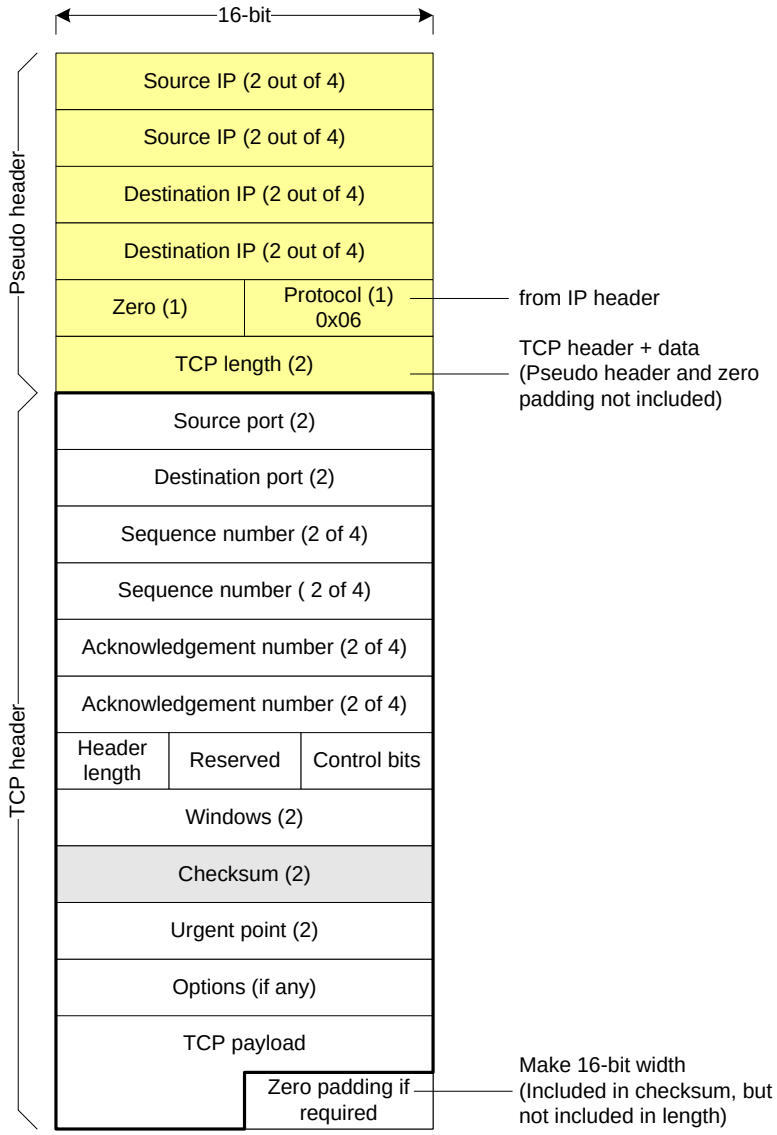
‘compute_udp_checksum()’ calculates checksum of UDP along with its pseudo IP header and returns the result after inversion.




### 5.1.5 compute_tcp_checksum ()

```
#include "eth_ip_udp_tcp_pkt.h"
uint32_t compute_tcp_checksum(pseudo_ip_hdr *ip_hdr
                                        , upd_hdr_t *tcp_hdr) ;
```

‘compute_tcp_checksum()’ calculates checksum of TCP along with its pseudo IP header and returns the result after inversion.

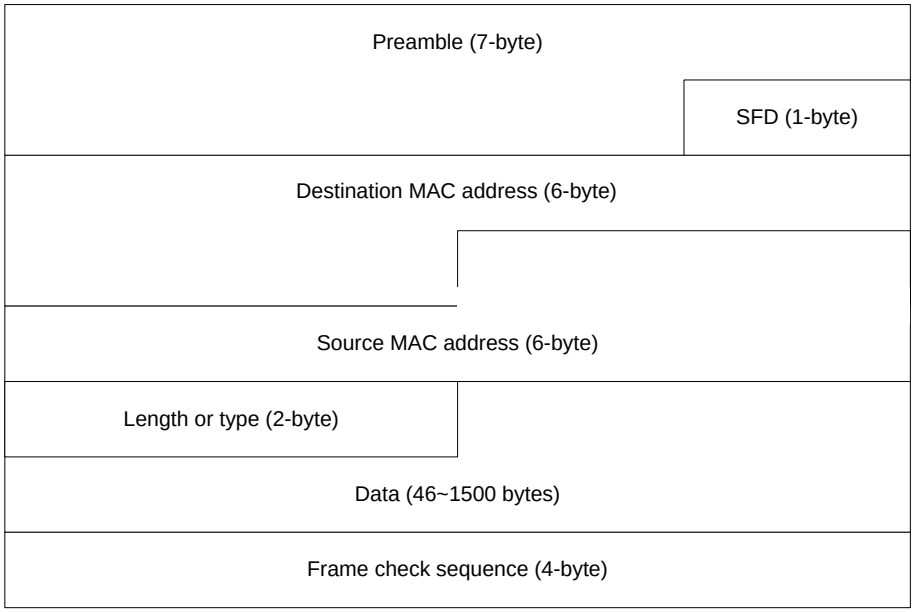



## 5.2 Packet header related API

### 5.2.1 populate_eth_hdr ()

```
#include "eth_ip_udp_pkt.h"
int populate_eth_hdr( eth_hdr_t *hdr // pointer to the buffer
                    , uint8_t    mac_src[6] // network order
                    , uint8_t    mac_dst[6] // network order
                    , uint16_t   type_leng);// host order, type an length value
```

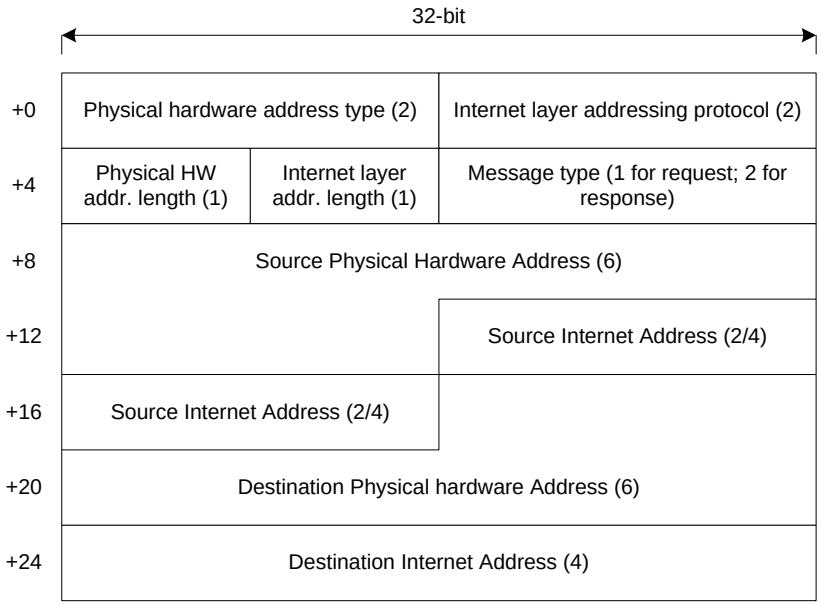
‘populate_eth_hdr()’ fills buffer pointed by ’hdr’ with Ethernet header (MAC destination to type-length) and returns the number of byes of the header.




### 5.2.2 populate_arp_hdr ()

```
#include "eth_ip_udp_pkt.h"
int populate_arp_hdr( arp_hdr_t *hdr
                    , uint16_t   type      // message type 0: ARP req, 2: ARP reply
                    , uint8_t    mac_src[6] // network order
                    , uint8_t    mac_dst[6] // network order
                    , uint32_t   ip_src     // host order
                    , uint32_t   ip_dst);   // host order
```

‘populate_arp_hdr()’ fills buffer pointed by ’hdr’ with ARP header and returns the number of byes of the header.

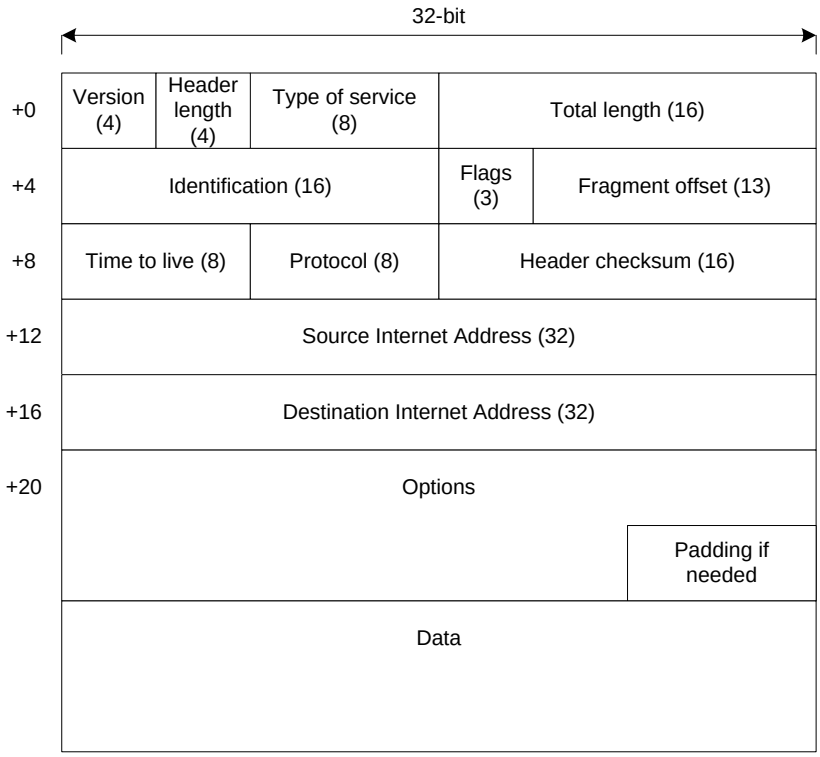



### 5.2.3 populate_ip_hdr()

```
#include "eth_ip_udp_pkt.h"
int populate_ip_hdr( ip_hdr_t *hdr
                   , uint32_t  ip_src    // host order
                   , uint32_t  ip_dst    // host order
                   , uint8_t   protocol  // specifies payload type
                   , uint16_t  payload_size); // pure payload size in bytes
```

‘populate_ip_hdr()’ fills buffer pointed by ’hdr’ with IP header and returns the number[5] of byes of the header.

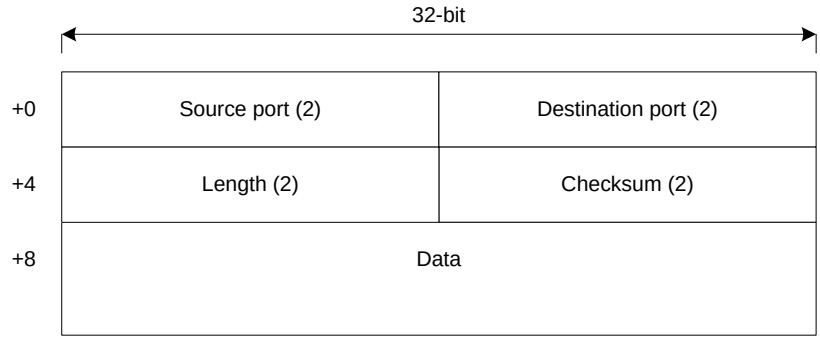
[5] It will be 20.




### 5.2.4 populate_udp_hdr()

```
#include "eth_ip_udp_pkt.h"
int populate_udp_hdr( udp_hdr_t *hdr
                    , uint16_t   port_src    // host order
                    , uint16_t   port_dst    // host order
                    , uint16_t   payload_size); // pure payload size in bytes
```

‘populate_udp_hdr()’ fills buffer pointed by ’hdr’ with UDP header and returns the number[6] of byes of the header.

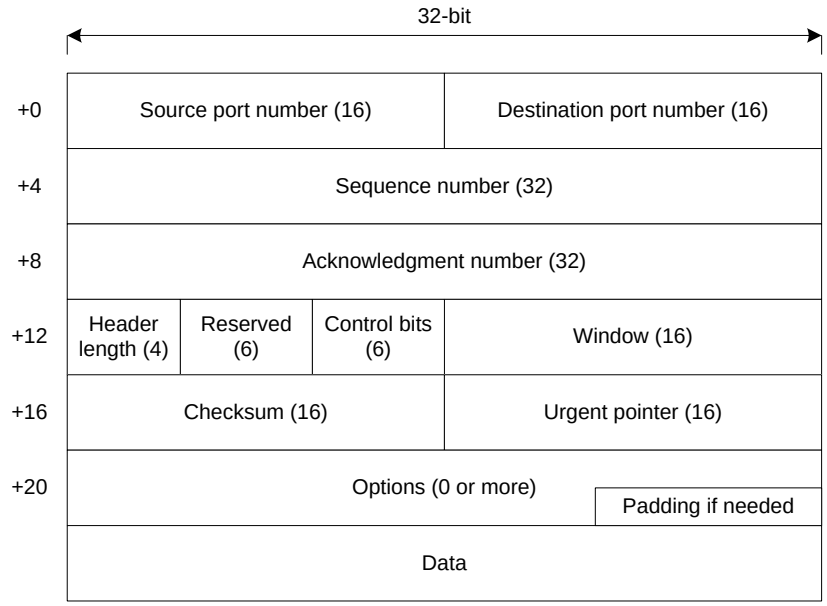



### 5.2.5 populate_tcp_hdr()

[6] It will be 8.

```
#include "eth_ip_udp_pkt.h"
int populate_tcp_hdr( tcp_hdr_t *hdr
                    , uint16_t   port_src // host order
                    , uint16_t   port_dst // host order
                    , uint32_t   num_seq  // host order
                    , uint32_t   num_ack  // host order
                    , uint16_t   payload_size); // pure payload size (not including header)
```

‘populate_tcp_hdr()’ fills buffer pointed by ’hdr’ with TCP header and returns the number[7] of byes of the header.




### 5.2.6 populate_ptpv2_msg_hdr()

```
#include "ptpv2_message.h"
int populate_ptpv2_msg_hdr( ptpv2_ctx_t     *ctx
                          , ptpv2_msg_hdr_t *msg_hdr
                          , uint8_t          type
                          , uint16_t         flag
                          , uint64_t         correction // 8-byte
                          , uint32_t         oui // 3-byte
                          , uint64_t         uuid // 5-byte
                          , uint16_t         ptp_port // 2-byte
                          , uint16_t         seq_id
                          , uint8_t          control);
```

‘populate_ptpv2_msg_hdr()’ fills buffer pointed by ’hdr’ with PTPv2 header and returns the number of byes of the header.

[7] It will be 20.

## 5.3 Packet related API

### 5.3.1 gen_eth_packet()

```
#include "eth_ip_udp_pkt.h"
int gen_eth_packet( uint8_t  *packet
                  , uint8_t   mac_src[6] // network order
                  , uint8_t   mac_dst[6] // network order
                  , uint16_t  type_leng  // host order
                  , uint16_t  payload_len// payload length
                  , uint8_t  *payload  // payload if not 0
                  , int       add_crc // append 4-byte CRC when 1
                  , int       add_preamble);// add 8-byte preamble
```

'gen_eth_packet()' fills buffer pointed by 'packet' with Ethernet header and payload. 'type_leng' and 'payload_len' can be the same, but it will differ when 'type_leng' specifies packet type. 'payload_len' should specify the number of bytes of the payload even though 'payload' is NULL, i.e., 0.

When 'add_crc' is 1 and 'payload_len' is smaller than 46, it appends padding of 0x00 and then adds 4-byte CRC at the end of 'payload' array. For this case, the number returned is the number including paddings.

It returns the number of bytes this routine touched; it returns the length of header when 'payload' is NULL.

### 5.3.2 gen_arp_packet()

```
#include "eth_ip_udp_pkt.h"
#define gen_arp_packet populate_arp_hdr
```

As ARP packet does not have any payload, ARP header is ARP packet itself.

### 5.3.3 gen_ip_packet()

```
#include "eth_ip_udp_pkt.h"
int gen_ip_packet( uint8_t  *packet
                 , uint32_t  ip_src     // host order
                 , uint32_t  ip_dst     // host order
                 , uint8_t   protocol   //
                 , uint16_t  payload_len// IP payload length
                 , uint8_t  *payload);  // payload if not 0
```

'gen_ip_packet()' fills buffer pointed by 'packet' with IP header and payload. 'payload_len' should specify the number of bytes of the payload even though 'payload' is NULL, i.e., 0. It returns the number of bytes this routine touched; it returns the length of header when 'payload' is NULL.

#### 5.3.4 gen_udp_packet()

```
#include "eth_ip_udp_pkt.h"
int gen_udp_packet( uint8_t  *packet
                  , uint16_t  port_src   // host order
                  , uint16_t  port_dst   // host order
                  , uint16_t  payload_len// UDP payload length
                  , uint8_t  *payload); // payload if not 0
```

'gen_udp_packet()' fills buffer pointed by 'packet' with UDP header and payload. 'payload_len' should specify the number of bytes of the payload even though 'payload' is NULL, i.e., 0. It returns the number of bytes this routine touched; it returns the length of header when 'payload' is NULL.

#### 5.3.5 gen_tcp_packet()

```
#include "eth_ip_udp_pkt.h"
int gen_tcp_packet( uint8_t  *packet
                  , uint16_t  port_src // host order order
                  , uint16_t  port_dst // host order order
                  , uint32_t  num_seq  // host order order
                  , uint32_t  num_ack  // host order order
                  , uint16_t  payload_len // IP payload length
                  , uint8_t  *payload); // pure payload
```

'gen_tcp_packet()' fills buffer pointed by 'packet' with TCP header and payload. 'payload_len' should specify the number of bytes of the payload even though 'payload' is NULL, i.e., 0. It returns the number of bytes this routine touched; it returns the length of header when 'payload' is NULL. Note that it does not update checksum, instead it fills 0 for it.

#### 5.3.6 gen_ptpv2_msg()

```
#include "ptpv2_message.h"
int gen_ptpv2_msg( ptpv2_ctx_t *ctx
                 , uint8_t      type // PTPv2 message type
                 , uint8_t     *msg // message buffer
                 , uint16_t     seq_id);
```

'gen_ptpv2_msg()' fills buffer pointed by 'msg' with PTPv2 header, body, and suffix.

## 5.4 Whole packet related API

### 5.4.1 gen_eth_arp_packet()

```
#include "eth_ip_udp_pkt.h"
int gen_eth_arp_packet( uint8_t  *packet
                      , uint8_t   mac_src[6] // network order
                      , uint8_t   mac_dst[6] // network order
                      , uint16_t  type       // ARP type
                      , uint32_t  ip_src     // host order
                      , uint32_t  ip_dst     // host order
                      , int add_crc
                      , int add_preamble);
```

'gen_eth_arp_packet()' fills buffer pointed by 'packet' with Ethernet frame, which contains Ethernet header and a whole ARP packet.

### 5.4.2 gen_eth_ip_packet()

```
#include "eth_ip_udp_pkt.h"
int gen_eth_ip_packet( uint8_t  *packet
                     , uint8_t   mac_src[6] // network order
                     , uint8_t   mac_dst[6] // network order
                     , uint32_t  ip_src     // host order
                     , uint32_t  ip_dst     // host order
                     , uint8_t   protocol   //
                     , uint16_t  payload_len// IP payload length
                     , uint8_t  *payload);  // payload if not 0
```

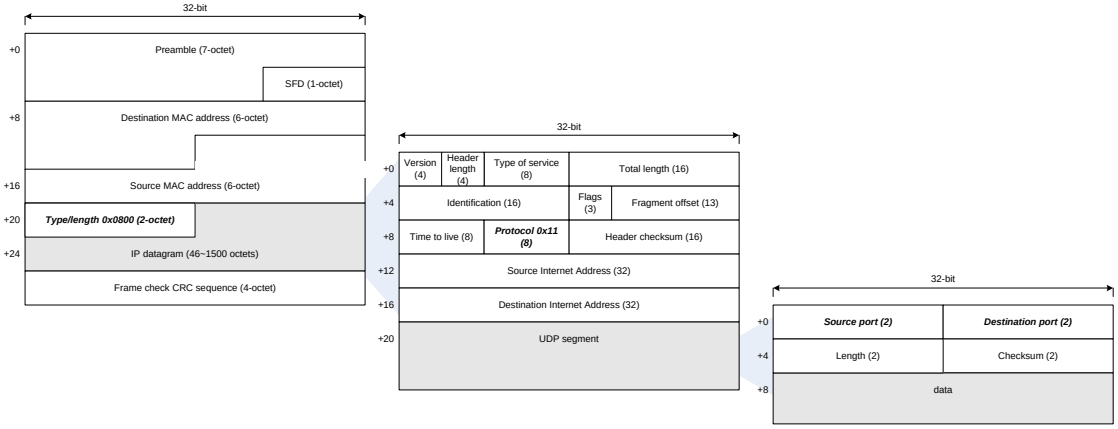
'gen_eth_ip_packet()' fills buffer pointed by 'packet' with Ethernet frame, which contains Ethernet header and a whole IP packet. 'payload_len' should specify the number of bytes of the IP pure payload even though 'payload' is NULL, i.e., 0. It returns the number of bytes this routine touched; it returns the length of header when 'payload' is NULL.

### 5.4.3 gen_eth_ip_udp_packet()

```
#include "eth_ip_udp_pkt.h"
int gen_eth_ip_udp_packet( uint8_t  *packet
                         , uint8_t   mac_src[6] // network order
                         , uint8_t   mac_dst[6] // network order
                         , uint32_t  ip_src     // host order
```

```
                , uint32_t  ip_dst     // host order
                , uint16_t  port_src   // 0x0001; host order
                , uint16_t  port_dst   // 0x0002; host order
                , uint16_t  udp_payload_len // UDP payload length
                , uint8_t  *payload // udp payload (pure)
                , int add_crc
                , int add_preamble);
```

‘gen_eth_ip_udp_packet()’ fills buffer pointed by ’packet’ with Ethernet frame, which contains Ethernet header and a whole UDP over IP packet. ‘payload_len’ should specify the number of bytes of the IP pure payload even though ‘payload’ is NULL, i.e., 0. It returns the number of bytes this routine touched; it returns the length of header when ‘payload’ is NULL.

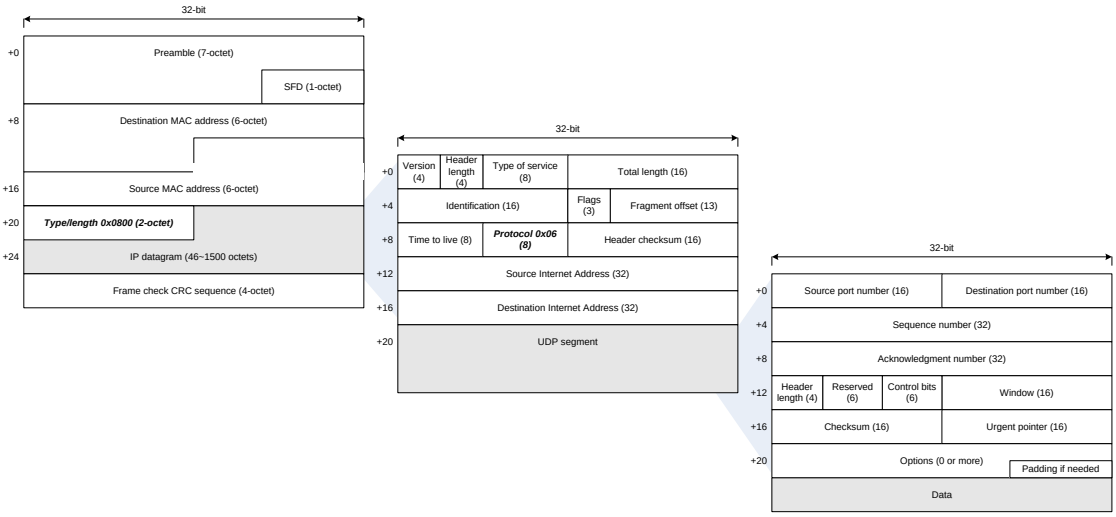



### 5.4.4 gen_eth_ip_tcp_packet()

```
#include "eth_ip_udp_pkt.h"
int gen_eth_ip_tcp_packet( uint8_t  *packet
                , uint8_t   mac_src[6] // network order
                , uint8_t   mac_dst[6] // network order
                , uint32_t  ip_src     // host order
                , uint32_t  ip_dst     // host order
                , uint16_t  port_src   // 0x0001; host order
                , uint16_t  port_dst   // 0x0001; host order
                , uint32_t  num_seq    // host order
                , uint32_t  num_ack    // host order
                , uint16_t  tcp_payload_len // TCP payload length
                , uint8_t  *payload // tcp payload (pure)
                , int add_crc
                , int add_preamble);
```

‘gen_eth_ip_tcp_packet()’ fills buffer pointed by ’packet’ with Ethernet frame, which contains Ethernet header and a whole TCP over IP packet. ‘payload_len’ should specify the number of bytes of the IP pure payload even though ‘payload’ is NULL, i.e., 0. It returns the number of bytes this routine touched; it

returns the length of header when ‘payload’ is NULL. It will update TCP header checksum using pseudo header information.




### 5.4.5 gen_ptpv2_ethernet()

```
#include "ptpv2_message.h"
int gen_ptpv2_msg_ethernet ( ptpv2_ctx_t *ctx
                           , uint8_t     *msg
                           , ptpv2_msg_hdr_t *hdr
                           , Timestamp_t     *time
                           , PortIdentity_t  *port
                           , uint8_t      mac_src[6]
                           , int          add_crc
                           , int          add_preamble);
```

‘gen_ptpv2_ethernet()’ fills buffer pointed by ’packet’ with Ethernet frame, which contains Ethernet header and a whole PTPv2 message. It uses 0x88F7 for Ethernet type-length value.

### 5.4.6 gen_ptpv2_upd_ip_ethernet()

```
#include "ptpv2_message.h"
int gen_ptpv2_msg_udp_ip_ethernet( ptpv2_ctx_t *ctx
                                 , uint8_t     *msg
                                 , ptpv2_msg_hdr_t *hdr
                                 , Timestamp_t     *time
                                 , PortIdentity_t  *port
                                 , uint32_t     ip_src
                                 , uint8_t      mac_src[6]
                                 , int          add_crc
                                 , int          add_preamble);
```

‘gen_ptpv2_udp_ip_ethrnet()’ fills buffer pointed by ’packet’ with Ethernet frame, which contains Ethernet header and a whole PTPv2 message over UDP over IP packet. It uses following UDP port and IP address for the destination.

- ✧ For event message
  - UDP port: 319
  - IP destination: 0xE0000181
  - MAC destination: 0x01_00_5E_00_01_81
- ✧ For general message
  - UDP port: 320
  - IP destination: 0xE000006B
  - MAC dstination: 0x01_00_5E_00_00_6B

## 5.5 Parsing API

### 5.5.1 parser_eth_packet ()

```
#include "eth_ip_udp_tcp_pkt.h"
int parser_eth_packet(uint8_t *pkt, int leng)
```

‘parser_eth_packet()’ interprets data in ‘pkt’ buffer as Ethernet frame.

### 5.5.2 parser_ip_packet ()

```
#include "eth_ip_udp_tcp_pkt.h"
int parser_ip_packet(uint8_t *pkt, int leng)
```

‘parser_ip_packet()’ interprets data in ‘pkt’ buffer as IP frame.

### 5.5.3 parser_udp_packet ()

```
#include "eth_ip_udp_tcp_pkt.h"
int parser_udp_packet(uint8_t *pkt, int leng)
```

‘parser_udp_packet()’ interprets data in ‘pkt’ buffer as UDP frame.

### 5.5.4 parser_tcp_packet ()

```
#include "eth_ip_udp_tcp_pkt.h"
int parser_tcp_packet(uint8_t *pkt, int leng)
```

‘parser_udp_packet()’ interprets data in ‘pkt’ buffer as TCPP frame.

## 6 References

[1] IEEE Standard Verilog Hardware Description Language, IEEE Std 1364-2001, IEEE Computer Society.
[2] The Verilog PLI Handbook, 2nd ED., S. Sutherland, KAP, 2002.
[3] ModelSim SE User's Manual, Mentor Graphics, 2003.
[4] VPI User Guide and Reference, Cadence Design Systems, 2002.

## 7 Index



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## Revision history

- ☐ 2019.05.30: Updated by Ando Ki.
- ☐ 2016.04.13: Started by Ando Ki (andoki@gmail.com or adki@future-ds.com).