GLIBC FILE Structure

K1a

PWN Week 3

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INTRODUCTION

$ Introduction

- 前兩堂提到了許多利用手法，然而實際在 PWN 的時候，很多時候都圍繞在這兩個問題
  - How to bypass ASLR?
  - How to control execution flow?

- 這堂我們會講一個常見、強大的利用手法
  - C standard library I/O mechanism

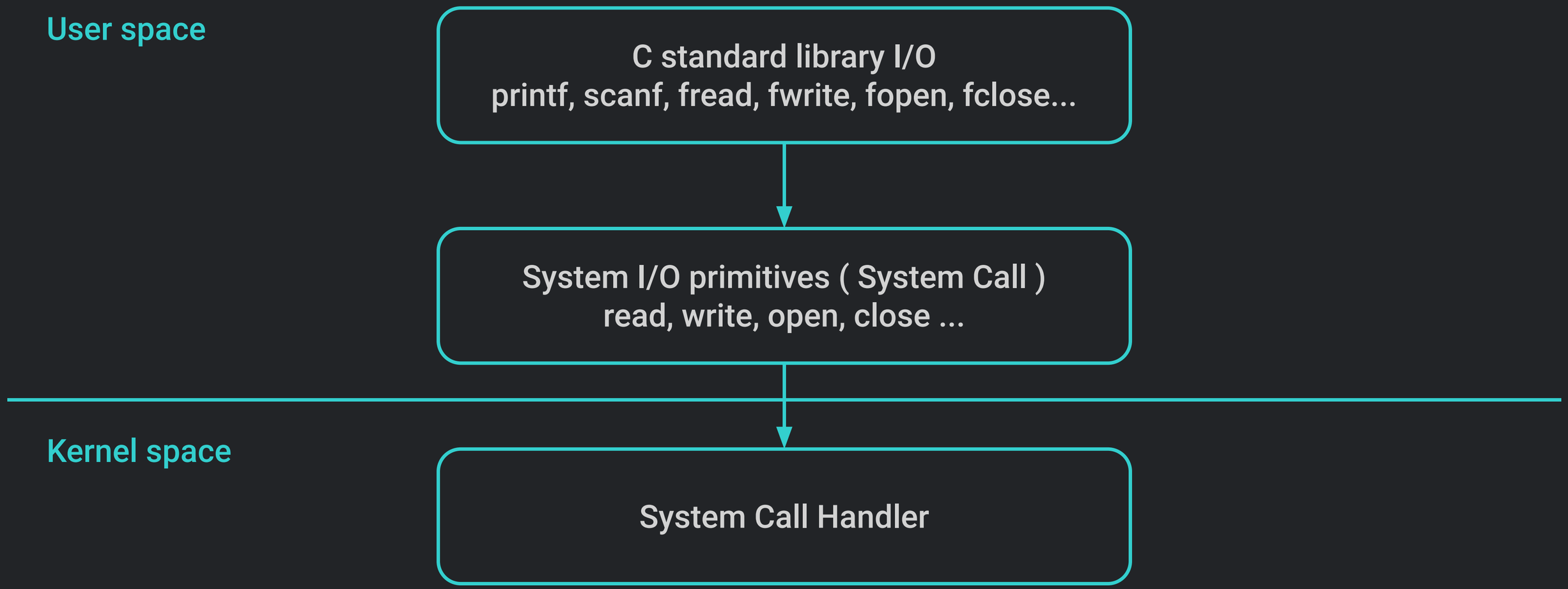
- 我們一樣是主要討論 GLIBC 2.31 上的實作
  - 許多 C 標準函式庫實作皆有相似的設計

$ C standard library I/O

- 如果你寫過 C, 相信你一定用過下面的 function
  - scanf
  - printf
  - fread
  - fwrite
  - fopen
  - fclose
  - …

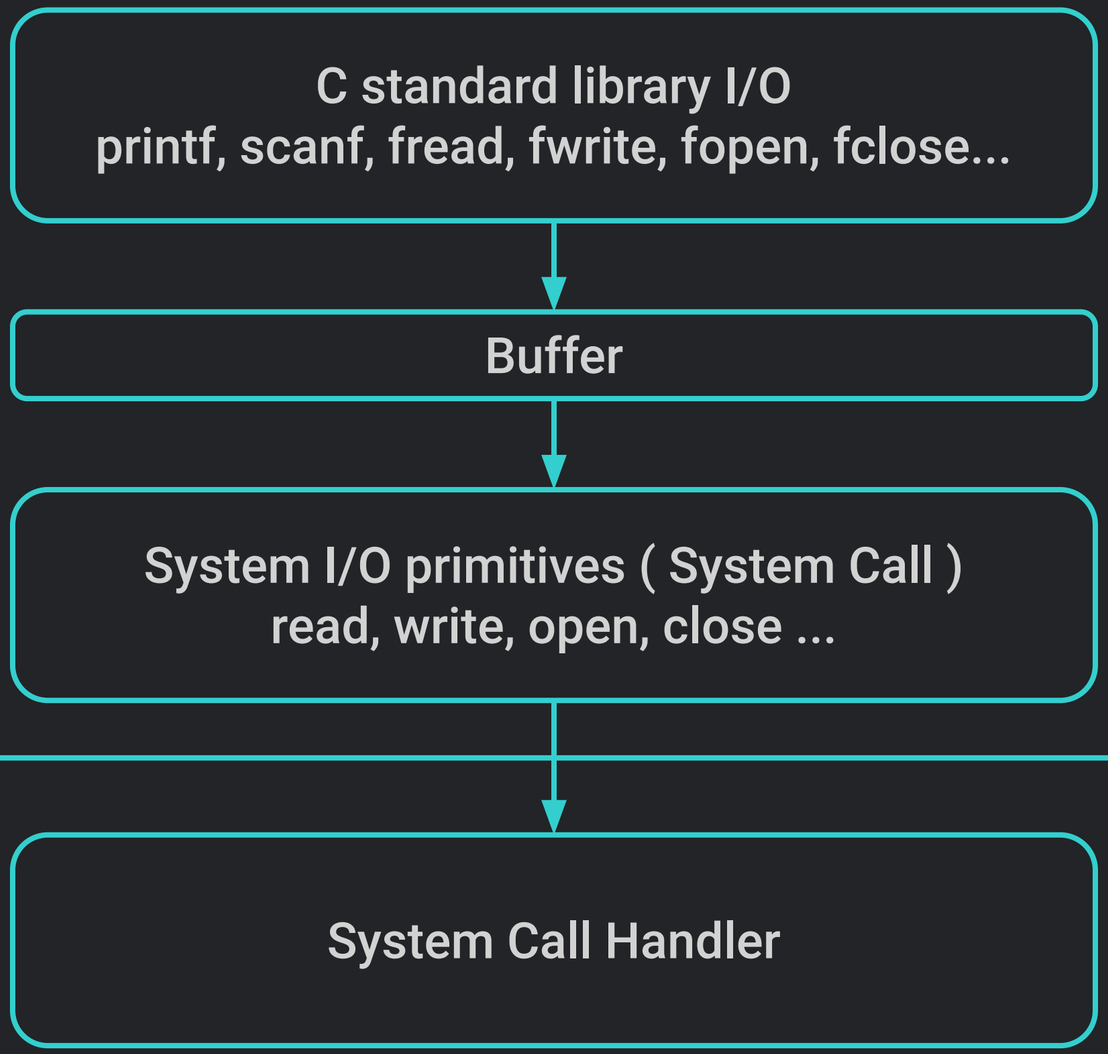
- Q: GLIBC 是如何去處理這些 function 底層的 I/O 的呢?

$ High-level overview



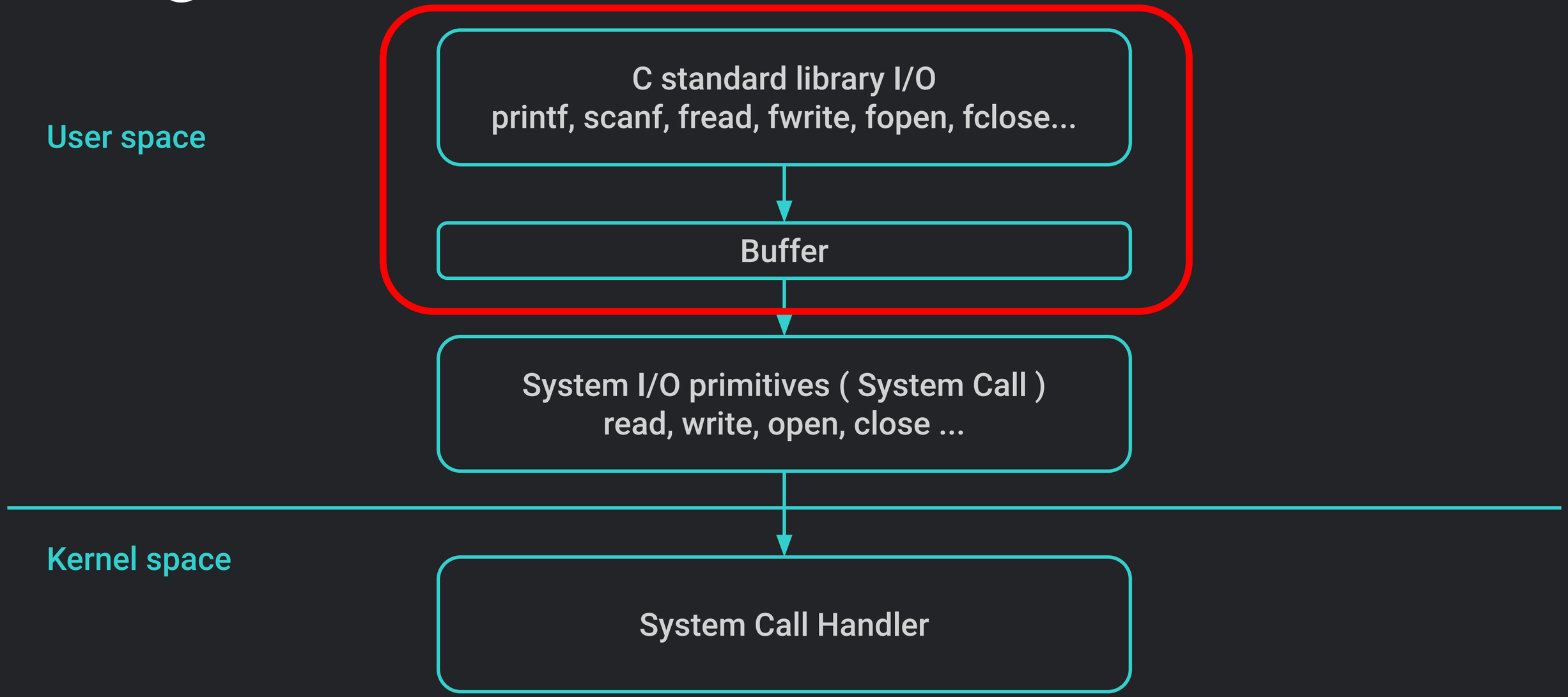
$ High-level overview

User space



Kernel space

$ High-level overview



BACKGROUND

$ FILE

- fopen
  - __fopen_internal (libio/iofopen.c)

```
FILE *
__fopen_internal (const char *filename, const char *mode, int is32)
{
 struct locked_FILE
 {
   struct _IO_FILE_plus fp;
   ...
} *new_f = (struct locked_FILE *) malloc (sizeof (struct locked_FILE));
 ...
}
```

$ _IO_FILE_plus

- struct _IO_FILE_plus (libio/libioP.h)

```
struct _IO_FILE_plus
{
 FILE file;
 const struct _IO_jump_t *vtable;
};
```

- libio/bits/types/FILE.h (libio/bits/types/FILE.h)

```
typedef struct _IO_FILE FILE;
```

$ _IO_FILE

- struct _IO_FILE (libio/bits/types/struct_FILE.h)
  - flags
  - Read buffer
  - Write buffer
  - Buffer base
  - Buffer end
  - chain
  - fileno

```
struct _IO_FILE
{
 int _flags;     /* High-order word is _IO_MAGIC; rest is flags. */

 /* The following pointers correspond to the C++ streambuf protocol. */
 char *_IO_read_ptr;   /* Current read pointer */
 char *_IO_read_end;   /* End of get area. */
 char *_IO_read_base;  /* Start of putback+get area. */
 char *_IO_write_base; /* Start of put area. */
 char *_IO_write_ptr;  /* Current put pointer. */
 char *_IO_write_end;  /* End of put area. */
 char *_IO_buf_base;   /* Start of reserve area. */
 char *_IO_buf_end; /* End of reserve area. */

 ...
 struct _IO_FILE *_chain;

 int _fileno;

 ...

};
```

$ _IO_FILE

- _flags (libio/libio.h)
  - _IO_UNBUFFERED
  - _IO_LINE_BUF

```
#define _IO_MAGIC         0xFBAD0000 /* Magic number */
#define _IO_MAGIC_MASK    0xFFFF0000
#define _IO_USER_BUF          0x0001 /* Don't deallocate buffer on close. */
#define _IO_UNBUFFERED        0x0002
#define _IO_NO_READS          0x0004 /* Reading not allowed.  */
#define _IO_NO_WRITES         0x0008 /* Writing not allowed.  */
#define _IO_EOF_SEEN          0x0010
#define _IO_ERR_SEEN          0x0020
#define _IO_DELETE_DONT_CLOSE 0x0040 /* Don't call close(_fileno) on close.  */
#define _IO_LINKED            0x0080 /* In the list of all open files.  */
#define _IO_IN_BACKUP         0x0100
#define _IO_LINE_BUF          0x0200
#define _IO_TIED_PUT_GET      0x0400 /* Put and get pointer move in unison.  */
#define _IO_CURRENTLY_PUTTING 0x0800
#define _IO_IS_APPENDING      0x1000
#define _IO_IS_FILEBUF        0x2000
                            /* 0x4000  No longer used, reserved for compat.  */
#define _IO_USER_LOCK         0x8000
```

$ _IO_FILE memory layout

$ _IO_FILE_plus (cont.)

- struct _IO_FILE_plus (libio/libioP.h)

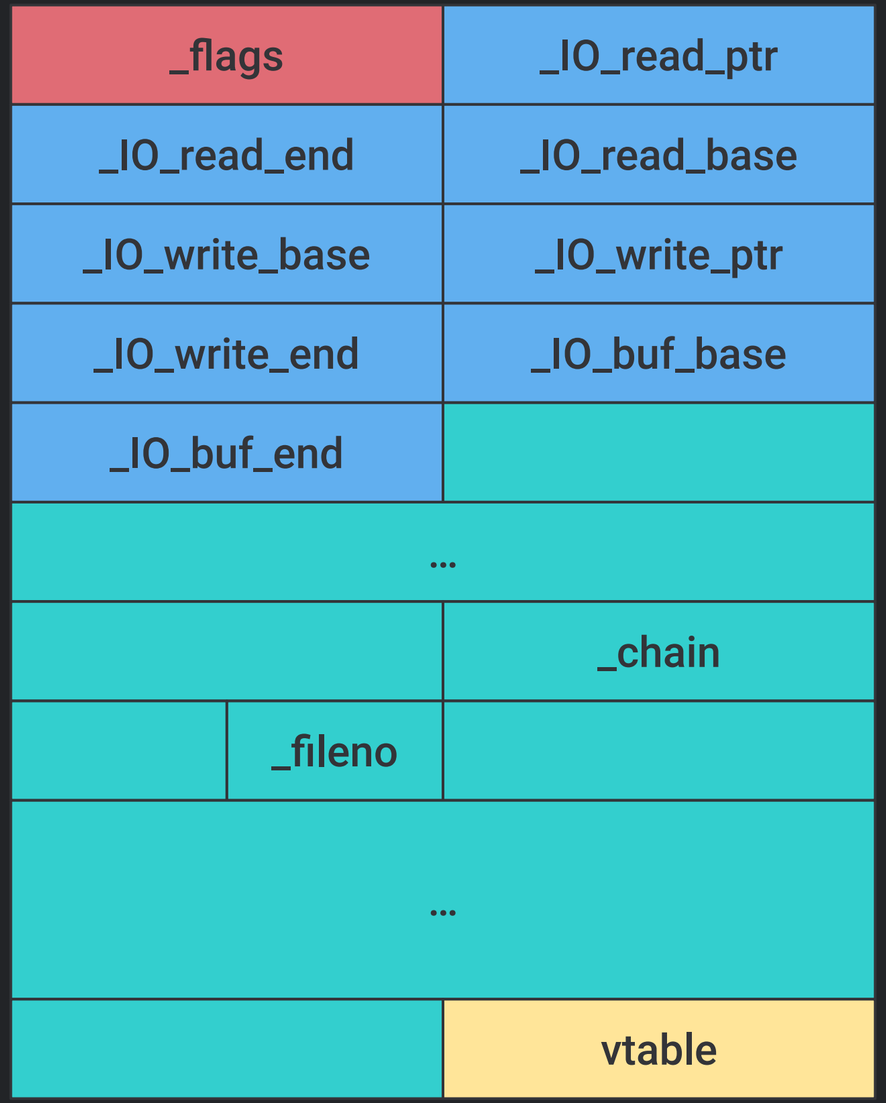
```
struct _IO_FILE_plus
{
 FILE file;
 const struct _IO_jump_t *vtable;
};
```

$ _IO_jump_t

- struct _IO_jump_t (libio/libioP.h)
  - vtable

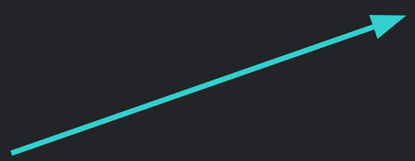
```
#define JUMP_FIELD(TYPE, NAME) TYPE NAME

struct _IO_jump_t
{
    JUMP_FIELD(size_t, __dummy);
    JUMP_FIELD(size_t, __dummy2);
    JUMP_FIELD(_IO_finish_t, __finish);
    JUMP_FIELD(_IO_overflow_t, __overflow);
    JUMP_FIELD(_IO_underflow_t, __underflow);
    JUMP_FIELD(_IO_underflow_t, __uflow);
    JUMP_FIELD(_IO_pbackfail_t, __pbackfail);
    /* showmany */
    JUMP_FIELD(_IO_xsputn_t, __xsputn);
    JUMP_FIELD(_IO_xsgetn_t, __xsgetn);
    JUMP_FIELD(_IO_seekoff_t, __seekoff);
    JUMP_FIELD(_IO_seekpos_t, __seekpos);
    JUMP_FIELD(_IO_setbuf_t, __setbuf);
    JUMP_FIELD(_IO_sync_t, __sync);
    JUMP_FIELD(_IO_doallocate_t, __doallocate);
    JUMP_FIELD(_IO_read_t, __read);
    JUMP_FIELD(_IO_write_t, __write);
    JUMP_FIELD(_IO_seek_t, __seek);
    JUMP_FIELD(_IO_close_t, __close);
    JUMP_FIELD(_IO_stat_t, __stat);
    JUMP_FIELD(_IO_showmanyc_t, __showmanyc);
    JUMP_FIELD(_IO_imbue_t, __imbue);
};
```

$ _IO_FILE_plus memory layout



$ _IO_FILE_plus instance

- Standard Input / Output / Error
  - libc data segment
  - _IO_2_1_stdin_
  - _IO_2_1_stdout_
  - _IO_2_1_stderr_
  - stdin, stdout, stderr
  - libio/libio.h, libio/stdio.c

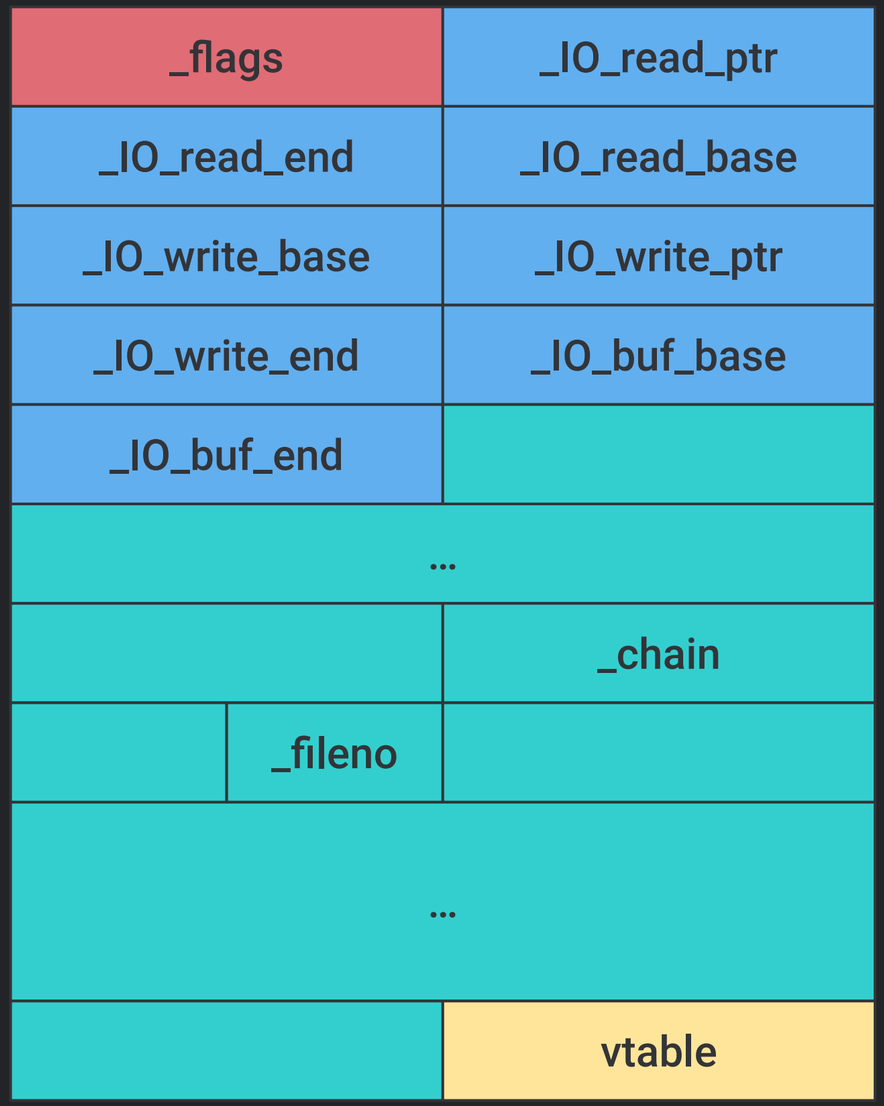


```
FILE *stdin = (FILE *) &_IO_2_1_stdin_;
FILE *stdout = (FILE *) &_IO_2_1_stdout_;
FILE *stderr = (FILE *) &_IO_2_1_stderr_;
```

- fopen()
  - heap
  - libio/iofopen.c

$ How buffered I/O works

_IO_2_1_stdout_




```c
printf("Hello World");
puts("");
```

* 因為這邊只是示意用，接下來的過程會簡化

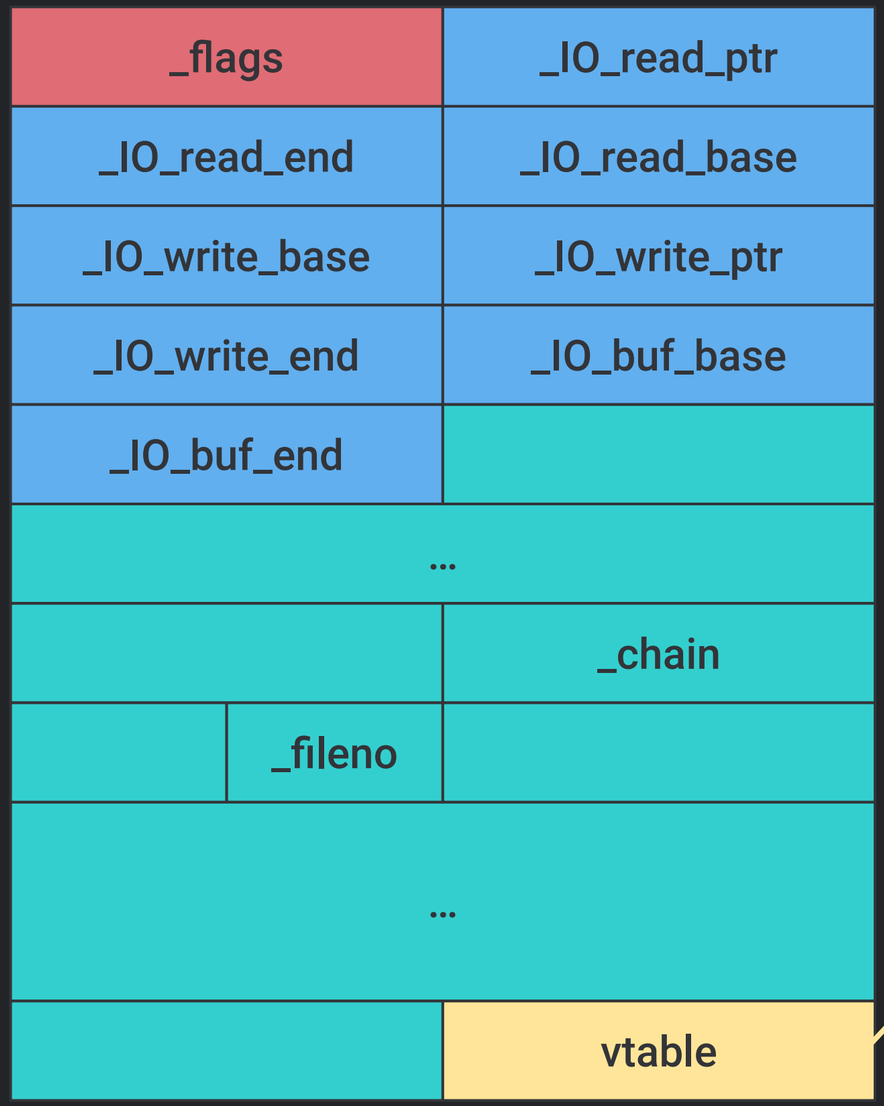
$ How buffered I/O works


```
printf("Hello World");
```

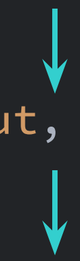
```
__vfprintf_internal (stdout, "Hello World", arg, 0);
```

$ How buffered I/O works

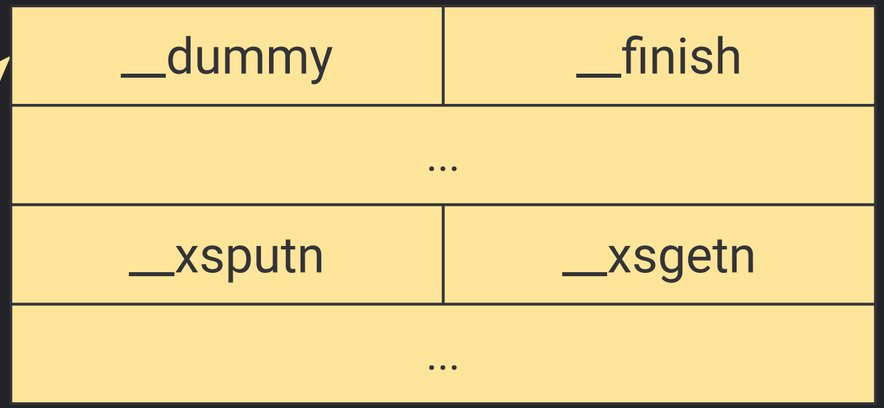
_IO_2_1_stdout_




```
printf("Hello World");
```

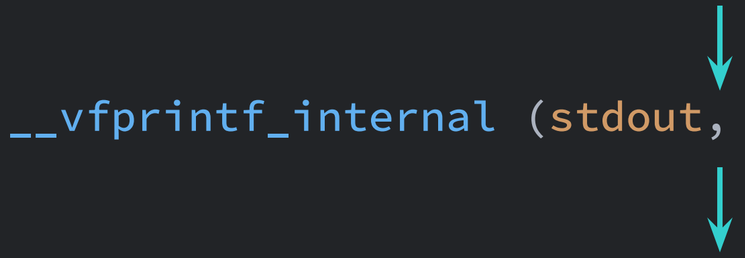


```
__vfprintf_internal (stdout, "Hello World", arg, 0);
```

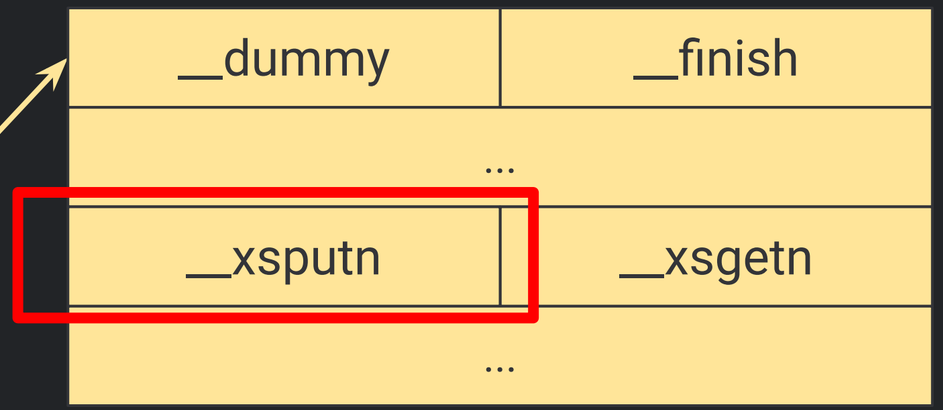



$ How buffered I/O works


```
printf("Hello World");
```

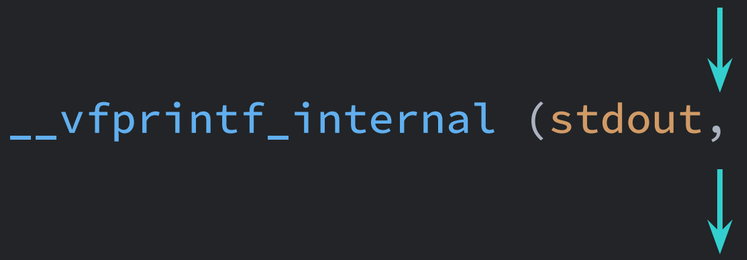


```
__vfprintf_internal (stdout, "Hello World", arg, 0);
```

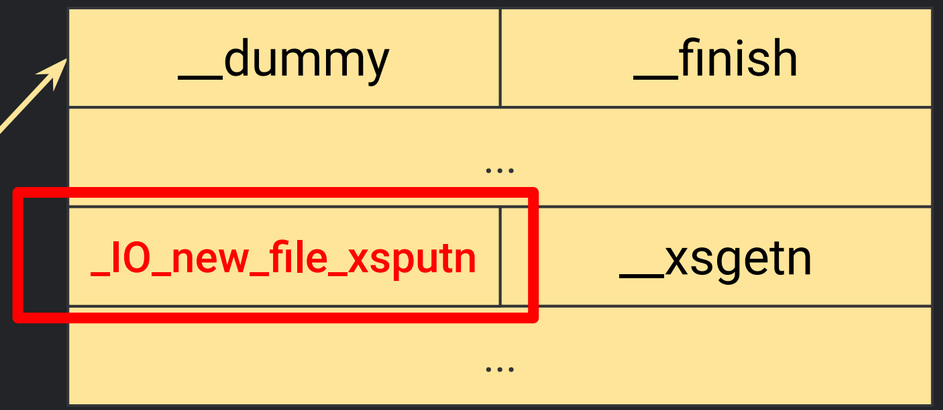



$ How buffered I/O works


```
printf("Hello World");
```

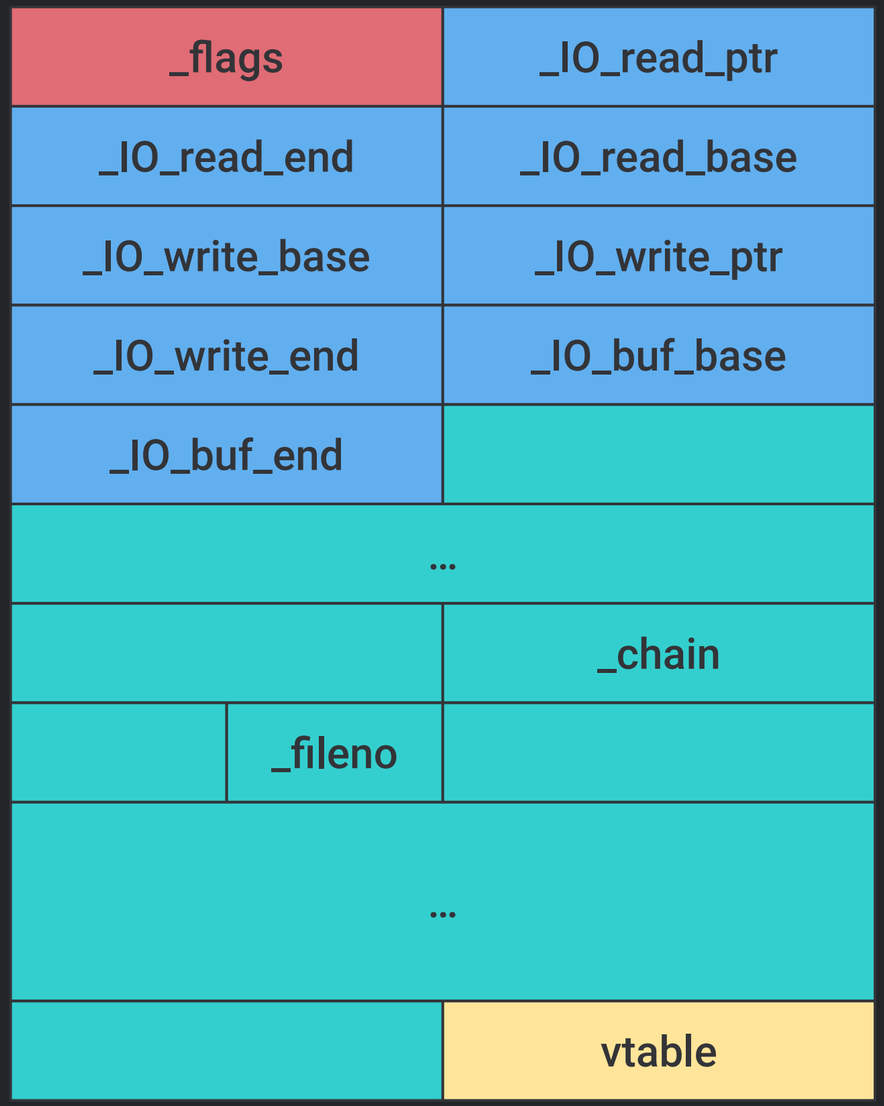


```
__vfprintf_internal (stdout, "Hello World", arg, 0);
```

$ How buffered I/O works

_IO_2_1_stdout_




```
printf("Hello World");
```

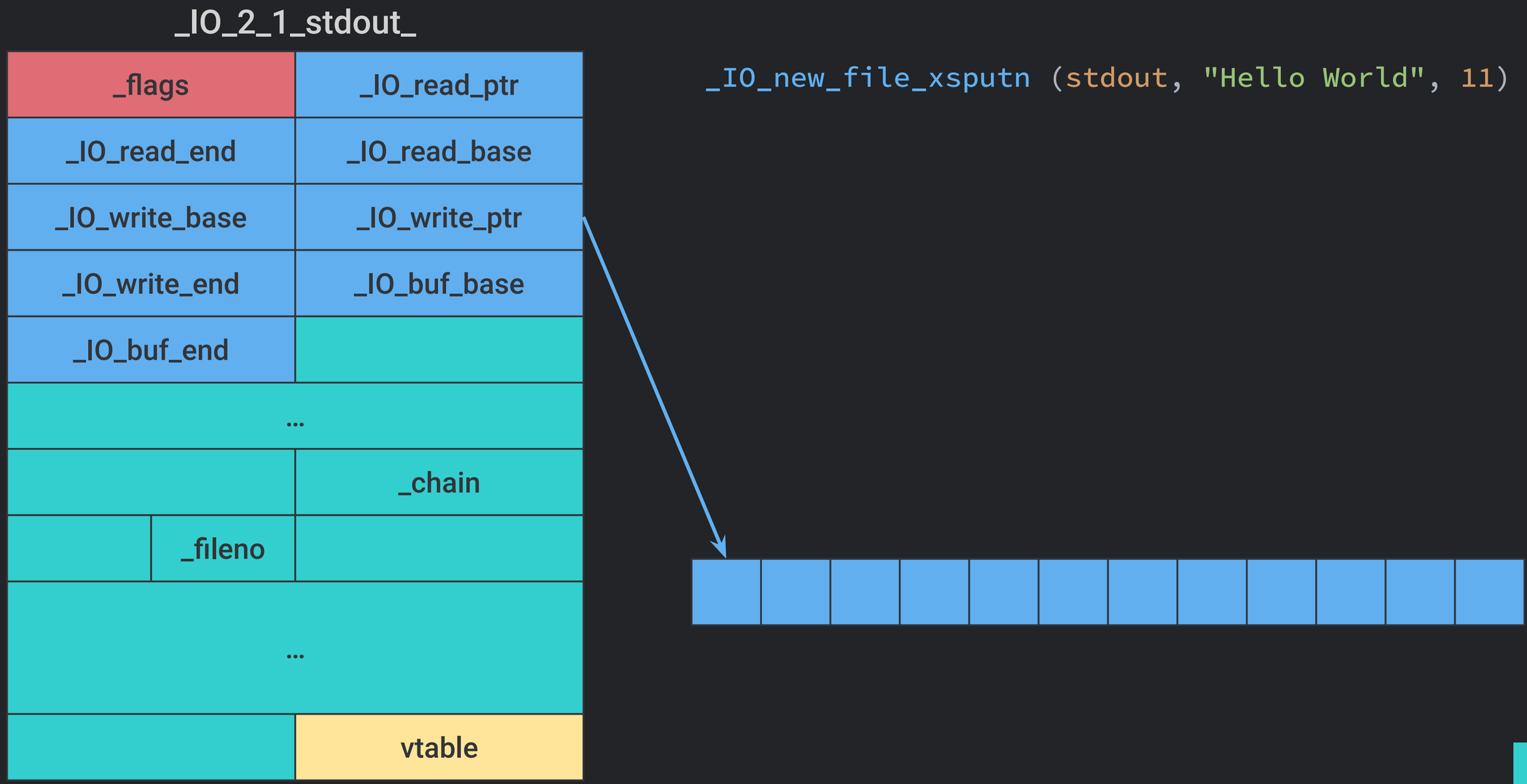
↓

```
__vfprintf_internal (stdout, "Hello World", arg, 0);
```

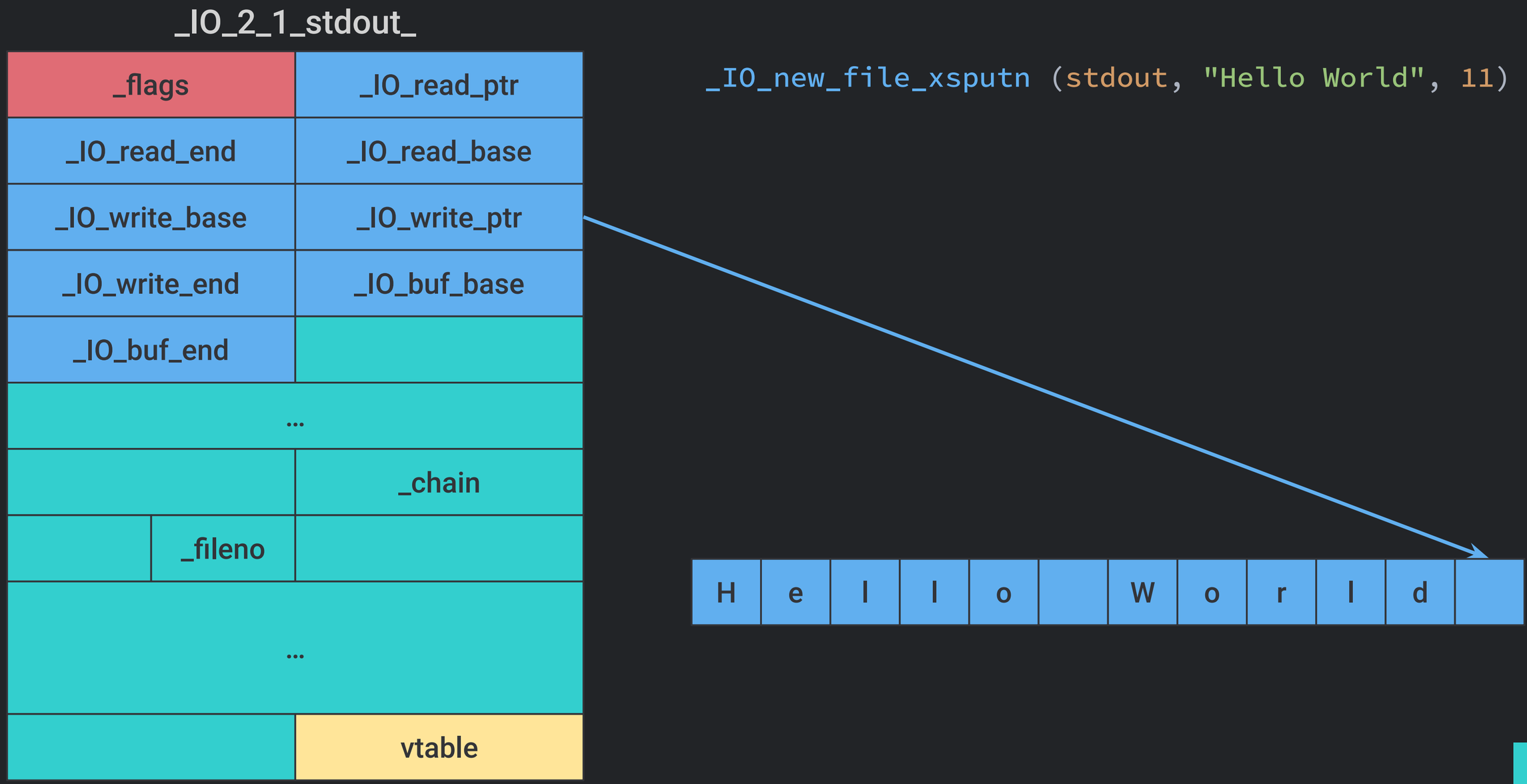
↓

```
_IO_new_file_xsputn (stdout, "Hello World", 11)
```

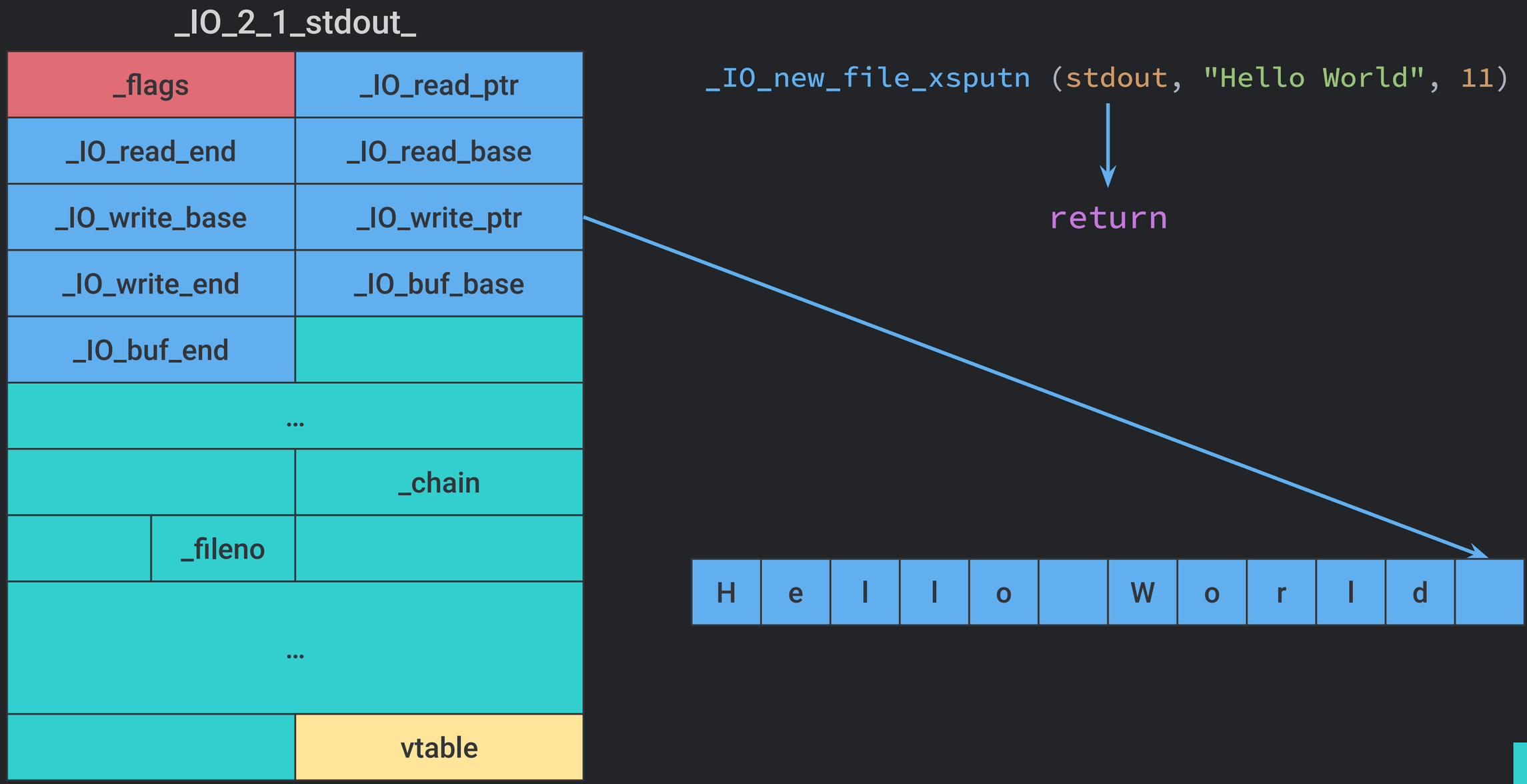
$ How buffered I/O works



$ How buffered I/O works

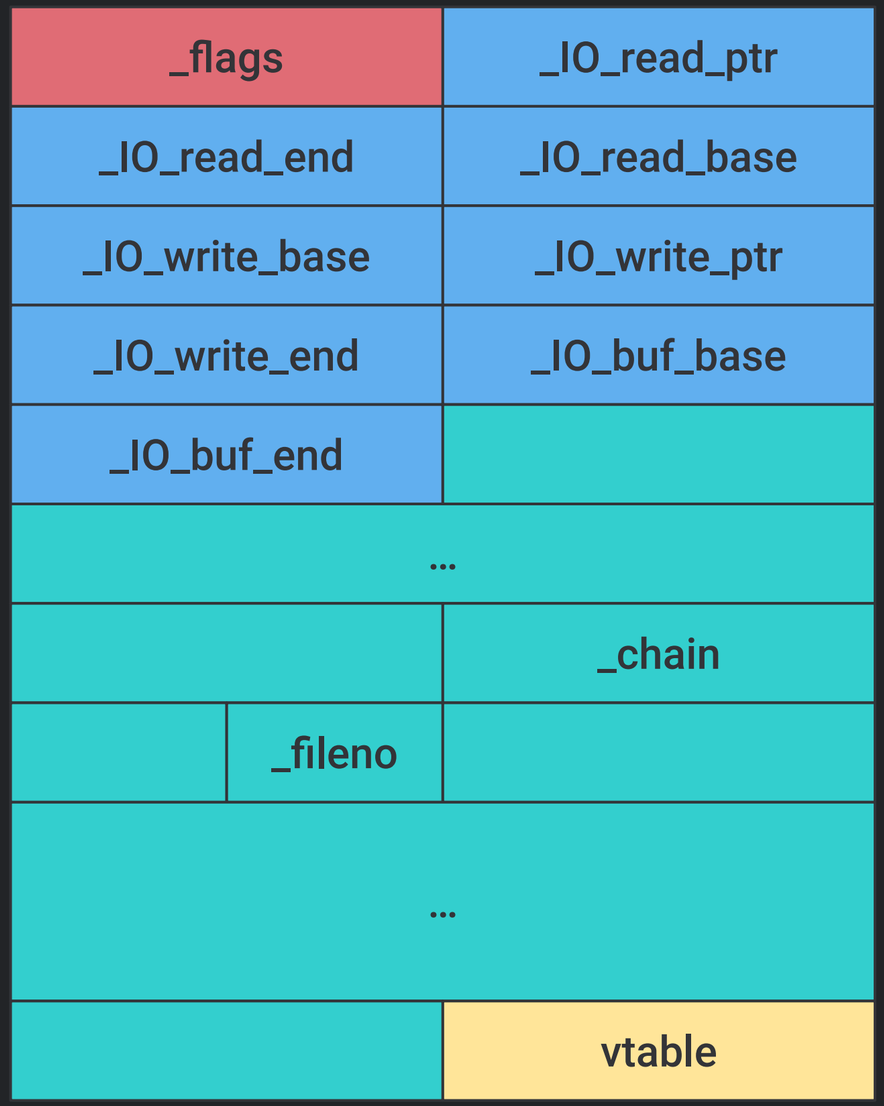


$ How buffered I/O works



$ How buffered I/O works

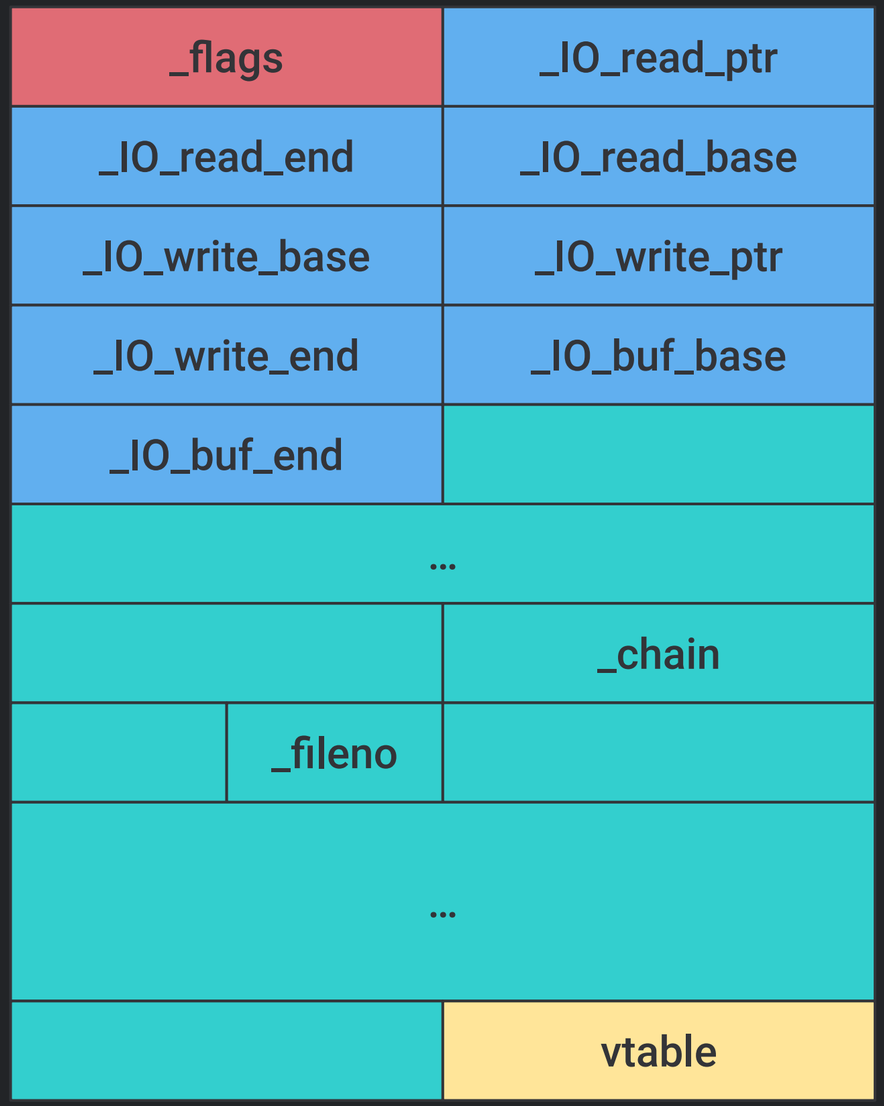
_IO_2_1_stdout_




```
puts("");
```

$ How buffered I/O works

_IO_2_1_stdout_




```
puts("");
```

↓

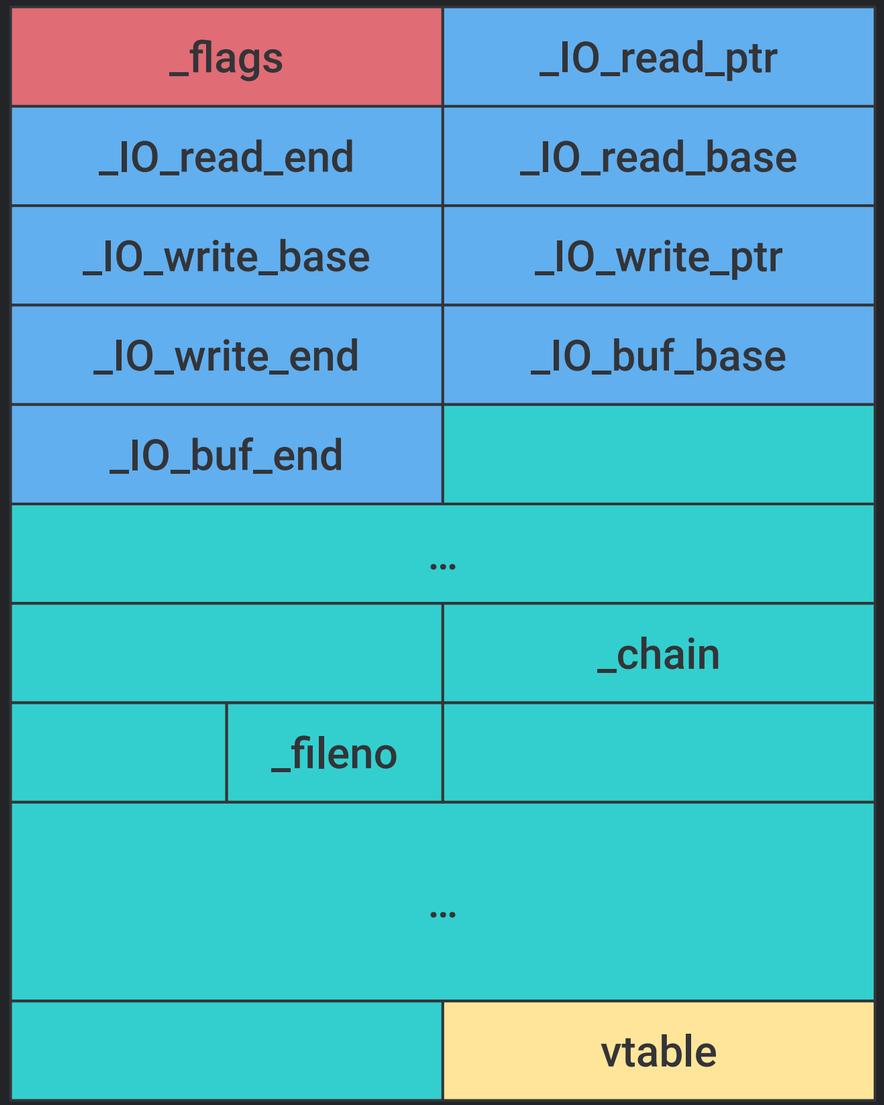
```
_IO_new_file_xsputn (stdout, "", 0)
```

↓

```
return
```

$ How buffered I/O works

_IO_2_1_stdout_

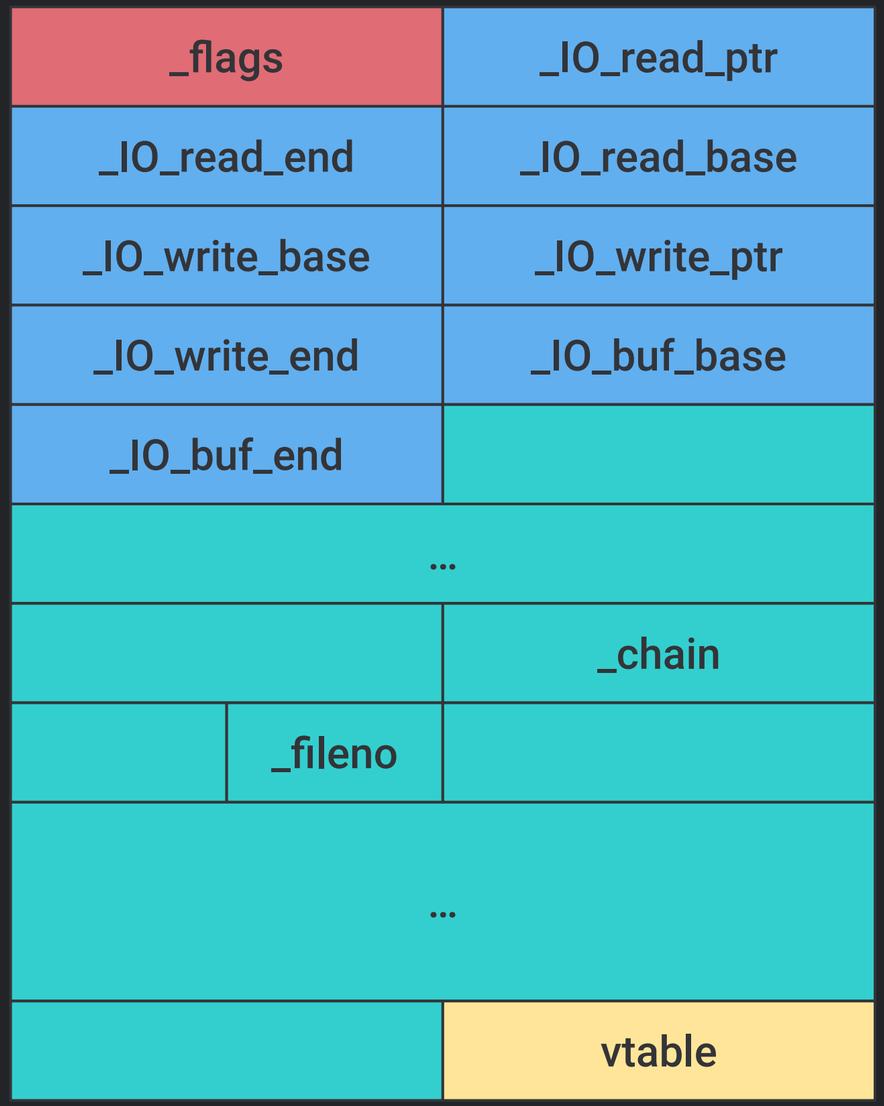



```
puts("");
```

```
_IO_new_file_overflow (stdout, '\n');
```

$ How buffered I/O works

_IO_2_1_stdout_




```
puts("");
```

↓

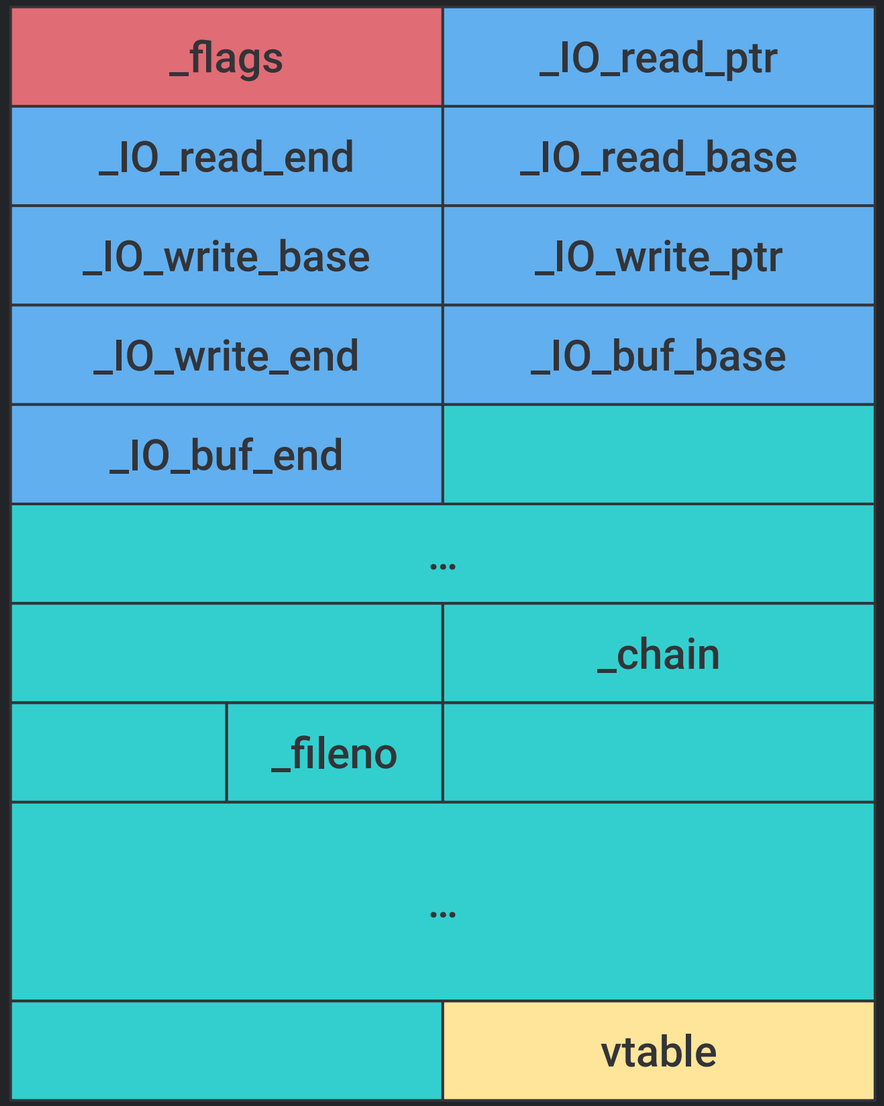
```
_IO_new_file_overflow (stdout, '\n');
```

↓

```
_IO_do_write (stdout, "Hello World\n", 12);
```

$ How buffered I/O works

_IO_2_1_stdout_




```
puts("");
```

↓

```
_IO_new_file_overflow (stdout, '\n');
```

↓

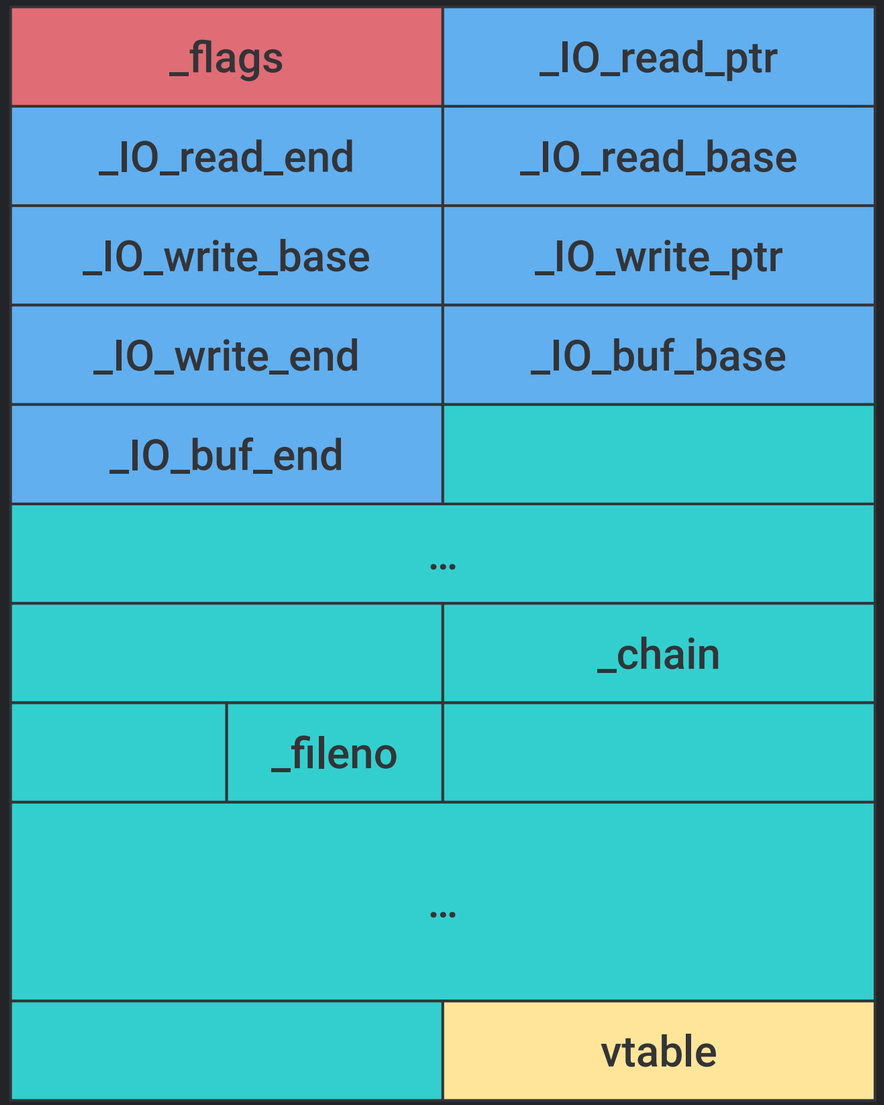
```
_IO_do_write (stdout, "Hello World\n", 12);
```

↓

```
sys_write (stdout._fileno, "Hello World\n", 12);
```

$ How buffered I/O works

_IO_2_1_stdout_




```
puts("");
```

↓

```
_IO_new_file_overflow (stdout, '\n');
```

↓

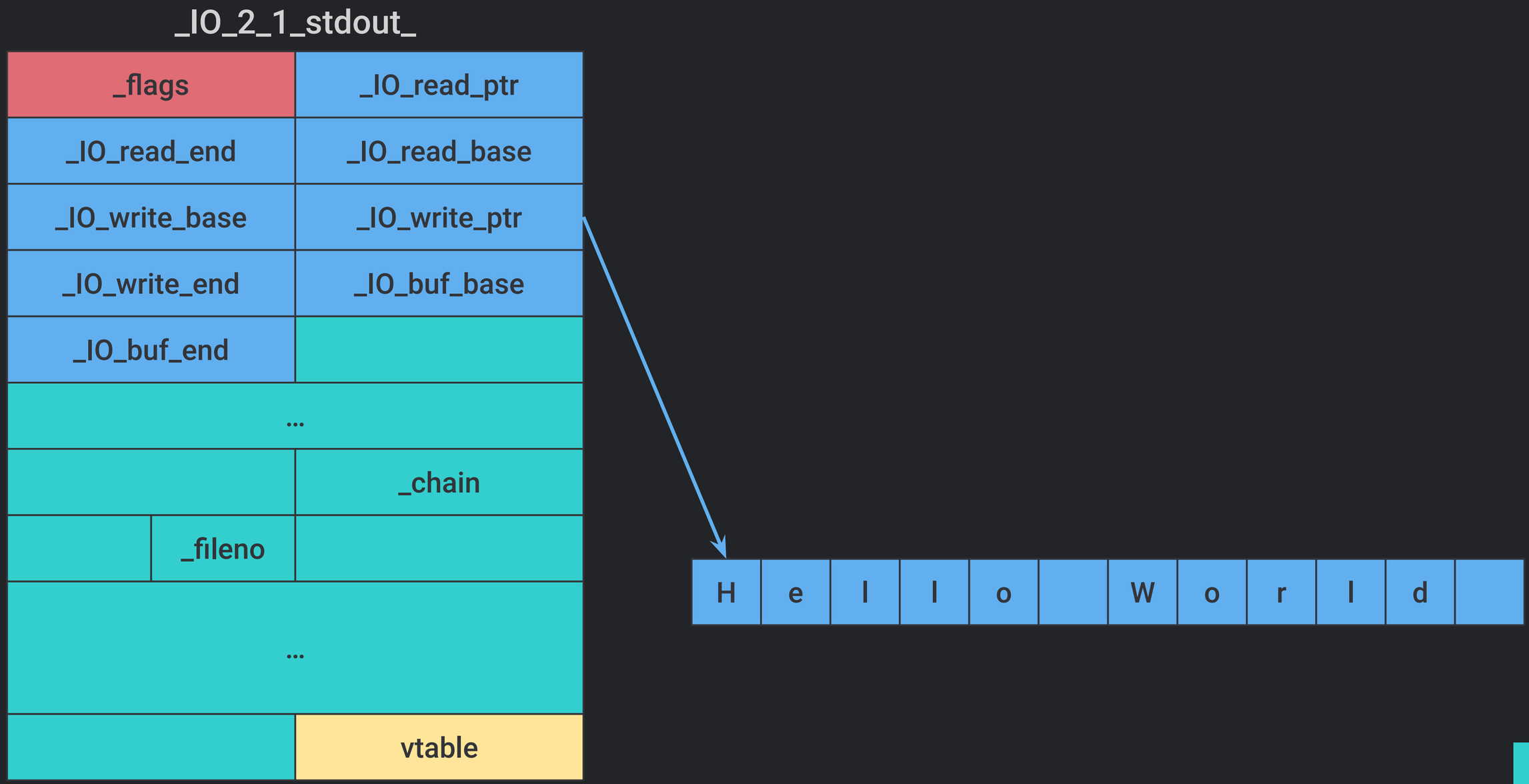
```
_IO_do_write (stdout, "Hello World\n", 12);
```

↓

```
sys_write (stdout._fileno, "Hello World\n", 12);
```

Hello World

$ How buffered I/O works



ARBITRARY READ

$ Arbitrary Read

- 想法
  - 將 buffer 的 base 設成 開始的位置
  - 將 buffer 的 ptr 設成 結束的位置
  - 在 output 的時候, 將 buffer 內容 output

- Q:
  - buffer base 是什麼?
  - buffer ptr 是什麼?
  - 如何將 buffer 內容 output?

$ _IO_file_xsputn

- libio/fileops.c
- line buffered
  - 當輸出字串小於 buffer 剩餘空間
    - 找 output 的字串有沒有包含 \n

```
size_t
_IO_new_file_xsputn (FILE *f, const void *data, size_t n)
{
 const char *s = (const char *) data;
 size_t to_do = n;
 int must_flush = 0;
 size_t count = 0;

 if (n <= 0)
   return 0;
 /* First figure out how much space is available in the buffer. */
 if ((f->_flags & _IO_LINE_BUF) && (f->_flags & _IO_CURRENTLY_PUTTING))
   {
     count = f->_IO_buf_end - f->_IO_write_ptr;
     if (count >= n) {
        const char *p;
        for (p = s + n; p > s; ) {
            if (*--p == '\n') {
                count = p - s + 1;
                must_flush = 1;
                break;
            }
        }
    }
   }
 else if (f->_IO_write_end > f->_IO_write_ptr)
   count = f->_IO_write_end - f->_IO_write_ptr; /* Space available. */
```

$ _IO_file_xsputn

- fully buffered / unbuffered
  - 計算 buffer 剩餘的空間

```
size_t
_IO_new_file_xsputn (FILE *f, const void *data, size_t n)
{
 const char *s = (const char *) data;
 size_t to_do = n;
 int must_flush = 0;
 size_t count = 0;

 if (n <= 0)
   return 0;
 /* First figure out how much space is available in the buffer. */
 if ((f->_flags & _IO_LINE_BUF) && (f->_flags & _IO_CURRENTLY_PUTTING))
   {
     count = f->_IO_buf_end - f->_IO_write_ptr;
     if (count >= n) {
        const char *p;
        for (p = s + n; p > s; ) {
            if (*--p == '\n') {
                count = p - s + 1;
                must_flush = 1;
                break;
            }
        }
    }
   }
 else if (f->_IO_write_end > f->_IO_write_ptr)
   count = f->_IO_write_end - f->_IO_write_ptr; /* Space available. */
```

$ _IO_file_xsputn

- 把 buffer 填滿

```
size_t
_IO_new_file_xsputn (FILE *f, const void *data, size_t n)
{
  ...
  /* Then fill the buffer. */
  if (count > 0)
    {
      if (count > to_do)
    count = to_do;
      f->_IO_write_ptr = __mempcpy (f->_IO_write_ptr, s, count);
      s += count;
      to_do -= count;
    }
  if (to_do + must_flush > 0)
    {
      size_t block_size, do_write;
      /* Next flush the (full) buffer. */
      if (_IO_OVERFLOW (f, EOF) == EOF)
    /* If nothing else has to be written we must not signal the
       caller that everything has been written.  */
    return to_do == 0 ? EOF : n - to_do;

      ...
    }
  return n - to_do;
}
```

$ _IO_file_xsputn

- 如果 buffer 空間不夠 / 遇到換行 (line buffered)
  - flush buffer
    - _IO_OVERFLOW
      - _IO_file_overflow

```
size_t
_IO_new_file_xsputn (FILE *f, const void *data, size_t n)
{
 ...
 /* Then fill the buffer. */
 if (count > 0)
  {
     if (count > to_do)
 count = to_do;
     f->_IO_write_ptr = __mempcpy (f->_IO_write_ptr, s, count);
     s += count;
     to_do -= count;
   }
 if (to_do + must_flush > 0)
   {
     size_t block_size, do_write;
     /* Next flush the (full) buffer. */
     if (_IO_OVERFLOW (f, EOF) == EOF)
/* If nothing else has to be written we must not signal the
   caller that everything has been written.  */
 return to_do == 0 ? EOF : n - to_do;

     ...
   }
 return n - to_do;
}
```

$ _IO_file_overflow

- libio/fileops.c
- _IO_NO_WRITES

- _flags &= ~_IO_NO_WRITES

```
#define _IO_NO_WRITES         0x0008 /* Writing not allowed.  */

int
_IO_new_file_overflow (FILE *f, int ch)
{
 if (f->_flags & _IO_NO_WRITES) /* SET ERROR */
   {
     ...
   }
  /* If currently reading or no buffer allocated. */
 if ((f->_flags & _IO_CURRENTLY_PUTTING) == 0 || f->_IO_write_base == NULL)
   {
     ...
   }
 if (ch == EOF)
   return _IO_do_write (f, f->_IO_write_base,
       f->_IO_write_ptr - f->_IO_write_base);
 ...
}
```

$ _IO_file_overflow

- libio/fileops.c
- 調整 buffer

- _flags &= ~_IO_NO_WRITES
- _flags |= _IO_CURRENTLY_PUTTING
- _IO_write_base != NULL

```
int
_IO_new_file_overflow (FILE *f, int ch)
{
 if (f->_flags & _IO_NO_WRITES) /* SET ERROR */
   {
     ...
   }
  /* If currently reading or no buffer allocated. */
 if ((f->_flags & _IO_CURRENTLY_PUTTING) == 0 || f->_IO_write_base == NULL)
   {
     ...
   }
 if (ch == EOF)
   return _IO_do_write (f, f->_IO_write_base,
       f->_IO_write_ptr - f->_IO_write_base);
 ...
}
```

$ _IO_file_overflow

- libio/fileops.c
- _IO_do_write

- _flags &= ~_IO_NO_WRITES
- _flags |= _IO_CURRENTLY_PUTTING
- _IO_write_base != NULL

```
int
_IO_new_file_overflow (FILE *f, int ch)
{
 if (f->_flags & _IO_NO_WRITES) /* SET ERROR */
   {
     ...
   }
  /* If currently reading or no buffer allocated. */
 if ((f->_flags & _IO_CURRENTLY_PUTTING) == 0 || f->_IO_write_base == NULL)
   {
     ...
   }
 if (ch == EOF)
   return _IO_do_write (f, f->_IO_write_base,
      f->_IO_write_ptr - f->_IO_write_base);
 ...
}
```

$ _IO_do_write

- libio/fileops.c

- _flags &= ~_IO_NO_WRITES
- _flags |= _IO_CURRENTLY_PUTTING
- _IO_write_base != NULL
- _IO_read_end = _IO_write_base

```
int
_IO_new_do_write (FILE *fp, const char *data, size_t to_do)
{
 return (to_do == 0
   || (size_t) new_do_write (fp, data, to_do) == to_do) ? 0 : EOF;
}
libc_hidden_ver (_IO_new_do_write, _IO_do_write)

static size_t
new_do_write (FILE *fp, const char *data, size_t to_do)
{
 size_t count;
 if (fp->_flags & _IO_IS_APPENDING)
   fp->_offset = _IO_pos_BAD;
 else if (fp->_IO_read_end != fp->_IO_write_base)
   {
     off64_t new_pos
 = _IO_SYSSEEK (fp, fp->_IO_write_base - fp->_IO_read_end, 1);
     if (new_pos == _IO_pos_BAD)
 return 0;
     fp->_offset = new_pos;
   }
 count = _IO_SYSWRITE (fp, data, to_do);
 ...
}
```

$ Arbitrary Read - Summary

- Q:
  - buffer base 是什麼?
    - _IO_write_base
  - buffer ptr 是什麼?
    - _IO_write_ptr
  - 如何將 buffer 內容 output?
    - _flags &= ~_IO_NO_WRITES
    - _flags |= _IO_CURRENTLY_PUTTING
    - _IO_write_base != NULL
    - _IO_read_end = _IO_write_base

    - _IO_write_end < _IO_write_ptr

$ LAB - FILE Note (R)

ARBITRARY WRITE

$ Arbitrary Write

- 想法
  - 在 input 的時候, input 內容會先寫到 buffer
  - 將 buffer 的 base 設成 開始的位置
  - 將 buffer 的 end 設成 結束的位置

- Q:
  - buffer base 是什麼?
  - buffer end 是什麼?
  - 如何將 input 寫到 buffer?

$ input functions

- scanf
  - _IO_file_underflow (libio/fileops.c)
- fread
  - _IO_file_xsgetn (libio/fileops.c)
    - _IO_file_underflow
- fgets
  - _IO_getline (libio/iogetline.c)
    - _IO_getline_info (libio/iogetline.c)
      - _IO_file_underflow

$ _IO_file_underflow

- libio/fileops.c
- 填滿 buffer

$ _IO_file_underflow

- Check flags

- _flags &= ~_IO_EOF_SEEN
- _flags &= ~_IO_NO_READS

```
int
_IO_new_file_underflow (FILE *fp)
{
 ssize_t count;

 /* C99 requires EOF to be "sticky".  */
 if (fp->_flags & _IO_EOF_SEEN)
   return EOF;

 if (fp->_flags & _IO_NO_READS)
   {
     fp->_flags |= _IO_ERR_SEEN;
     __set_errno (EBADF);
     return EOF;
   }
 if (fp->_IO_read_ptr < fp->_IO_read_end)
   return *(unsigned char *) fp->_IO_read_ptr;

 if (fp->_IO_buf_base == NULL)
   {
     /* Maybe we already have a push back pointer.  */
     if (fp->_IO_save_base != NULL)
{
   free (fp->_IO_save_base);
   fp->_flags &= ~_IO_IN_BACKUP;
}
     _IO_doallocbuf (fp);
   }
```

$ _IO_file_underflow

- Buffer 內還有 data

- _flags &= ~_IO_EOF_SEEN
- _flags &= ~_IO_NO_READS
- _IO_read_ptr >= _IO_read_end

```
int
_IO_new_file_underflow (FILE *fp)
{
 ssize_t count;

 /* C99 requires EOF to be "sticky".  */
 if (fp->_flags & _IO_EOF_SEEN)
   return EOF;

 if (fp->_flags & _IO_NO_READS)
   {
     fp->_flags |= _IO_ERR_SEEN;
     __set_errno (EBADF);
     return EOF;
   }
 if (fp->_IO_read_ptr < fp->_IO_read_end)
   return *(unsigned char *) fp->_IO_read_ptr;

 if (fp->_IO_buf_base == NULL)
   {
     /* Maybe we already have a push back pointer.  */
     if (fp->_IO_save_base != NULL)
{
   free (fp->_IO_save_base);
   fp->_flags &= ~_IO_IN_BACKUP;
}
     _IO_doallocbuf (fp);
   }
```

$ _IO_file_underflow

- 沒有 buffer

- _flags &= ~_IO_EOF_SEEN
- _flags &= ~_IO_NO_READS
- _IO_read_ptr >= _IO_read_end
- _IO_buf_base != NULL

```
int
_IO_new_file_underflow (FILE *fp)
{
 ssize_t count;

 /* C99 requires EOF to be "sticky".  */
 if (fp->_flags & _IO_EOF_SEEN)
   return EOF;

 if (fp->_flags & _IO_NO_READS)
   {
     fp->_flags |= _IO_ERR_SEEN;
     __set_errno (EBADF);
     return EOF;
   }
 if (fp->_IO_read_ptr < fp->_IO_read_end)
   return *(unsigned char *) fp->_IO_read_ptr;

 if (fp->_IO_buf_base == NULL)
   {
     /* Maybe we already have a push back pointer.  */
     if (fp->_IO_save_base != NULL)
{
  free (fp->_IO_save_base);
  fp->_flags &= ~_IO_IN_BACKUP;
}
     _IO_doallocbuf (fp);
   }
```

$ _IO_file_underflow

- flush stdout

- _flags &= ~_IO_EOF_SEEN
- _flags &= ~_IO_NO_READS
- _IO_read_ptr >= _IO_read_end
- _IO_buf_base != NULL

```
int
_IO_new_file_underflow (FILE *fp)
{
 ...
 if (fp->_flags & (_IO_LINE_BUF|_IO_UNBUFFERED))
   {
     _IO_acquire_lock (stdout);

     if ((stdout->_flags & (_IO_LINKED | _IO_NO_WRITES | _IO_LINE_BUF))
   == (_IO_LINKED | _IO_LINE_BUF))
 _IO_OVERFLOW (stdout, EOF);

     _IO_release_lock (stdout);
   }

 _IO_switch_to_get_mode (fp);

 fp->_IO_read_base = fp->_IO_read_ptr = fp->_IO_buf_base;
 fp->_IO_read_end = fp->_IO_buf_base;
 fp->_IO_write_base = fp->_IO_write_ptr = fp->_IO_write_end
   = fp->_IO_buf_base;

 count = _IO_SYSREAD (fp, fp->_IO_buf_base,
          fp->_IO_buf_end - fp->_IO_buf_base);
 if (count <= 0)
   {
     if (count == 0)
 fp->_flags |= _IO_EOF_SEEN;
```

$ _IO_file_underflow

- 從 _IO_buf_base 讀到 _IO_buf_end

- _flags &= ~_IO_EOF_SEEN
- _flags &= ~_IO_NO_READS
- _IO_read_ptr >= _IO_read_end
- _IO_buf_base != NULL

```
int
_IO_new_file_underflow (FILE *fp)
{
 ...
 if (fp->_flags & (_IO_LINE_BUF|_IO_UNBUFFERED))
   {
     _IO_acquire_lock (stdout);

     if ((stdout->_flags & (_IO_LINKED | _IO_NO_WRITES | _IO_LINE_BUF))
   == (_IO_LINKED | _IO_LINE_BUF))
 _IO_OVERFLOW (stdout, EOF);

     _IO_release_lock (stdout);
   }

 _IO_switch_to_get_mode (fp);

 fp->_IO_read_base = fp->_IO_read_ptr = fp->_IO_buf_base;
 fp->_IO_read_end = fp->_IO_buf_base;
 fp->_IO_write_base = fp->_IO_write_ptr = fp->_IO_write_end
   = fp->_IO_buf_base;

 count = _IO_SYSREAD (fp, fp->_IO_buf_base,
         fp->_IO_buf_end - fp->_IO_buf_base);
 ...
}
libc_hidden_ver (_IO_new_file_underflow, _IO_file_underflow)
```

$ Arbitrary Write - Summary

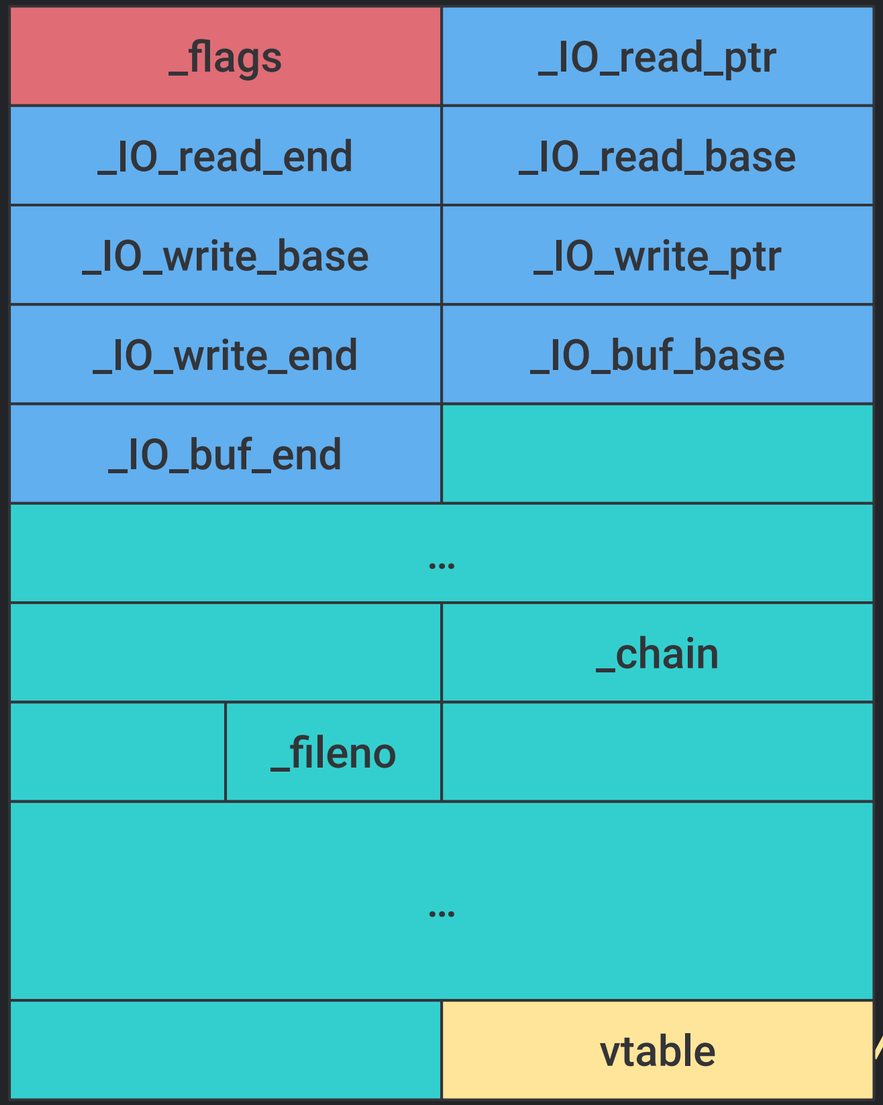
- Q:
  - buffer base 是什麼?
    - _IO_buf_base
  - buffer end 是什麼?
    - _IO_buf_end
  - 如何將 input 寫到 buffer?
    - _flags &= ~_IO_EOF_SEEN
    - _flags &= ~_IO_NO_READS
    - _IO_read_ptr >= _IO_read_end
    - _IO_buf_base != NULL

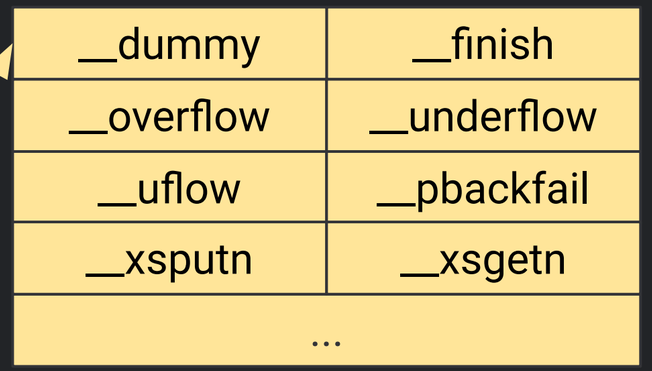
$ LAB - FILE Note (W)

HIJACK VTABLE

$ Hijack vtable

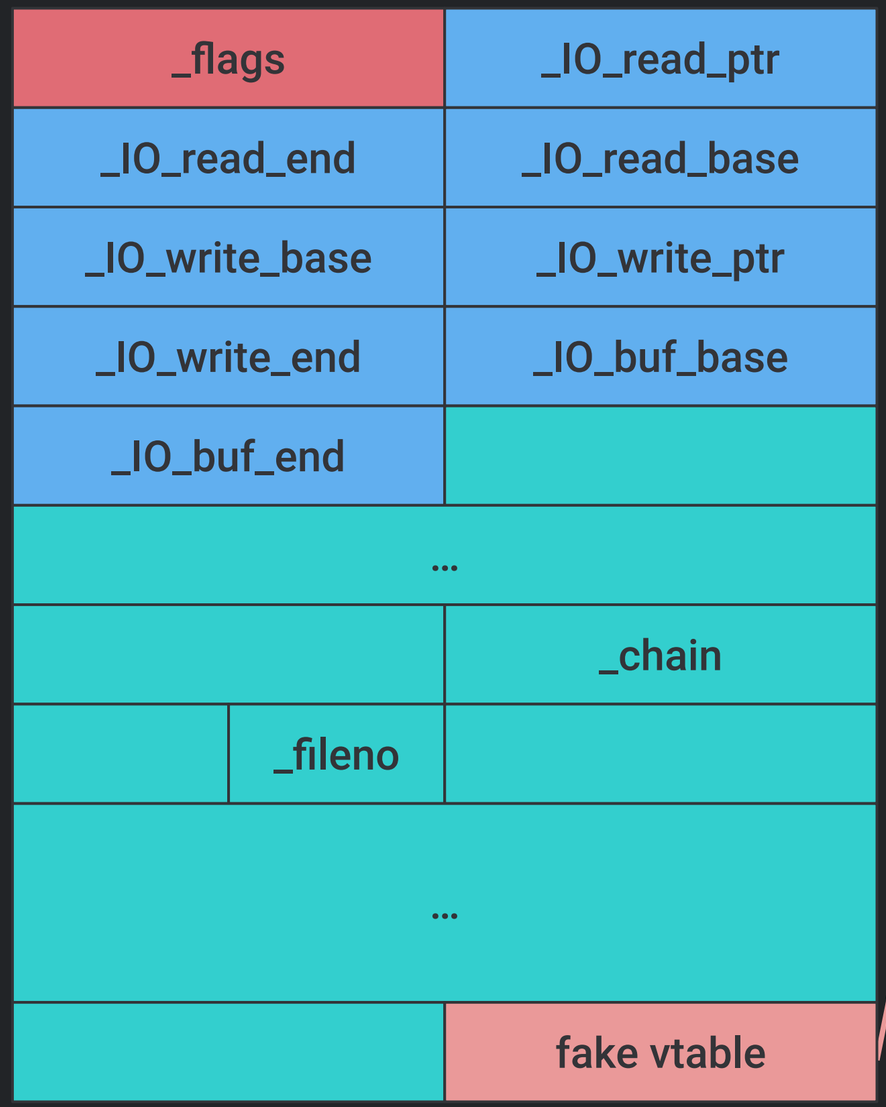
- 直接改 vtable pointer?

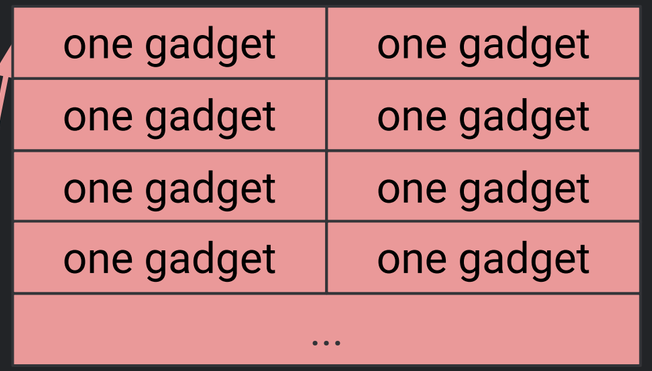


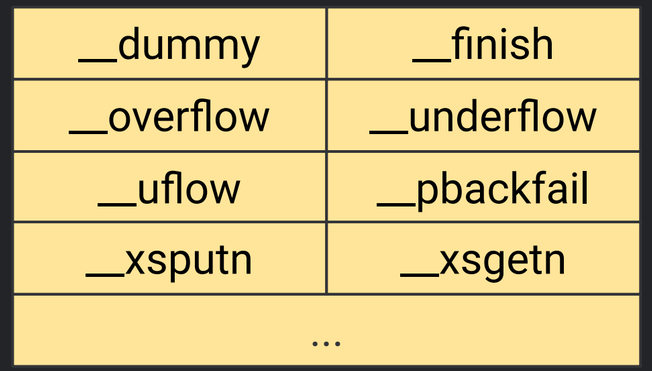


$ Hijack vtable

- 直接改 vtable pointer?



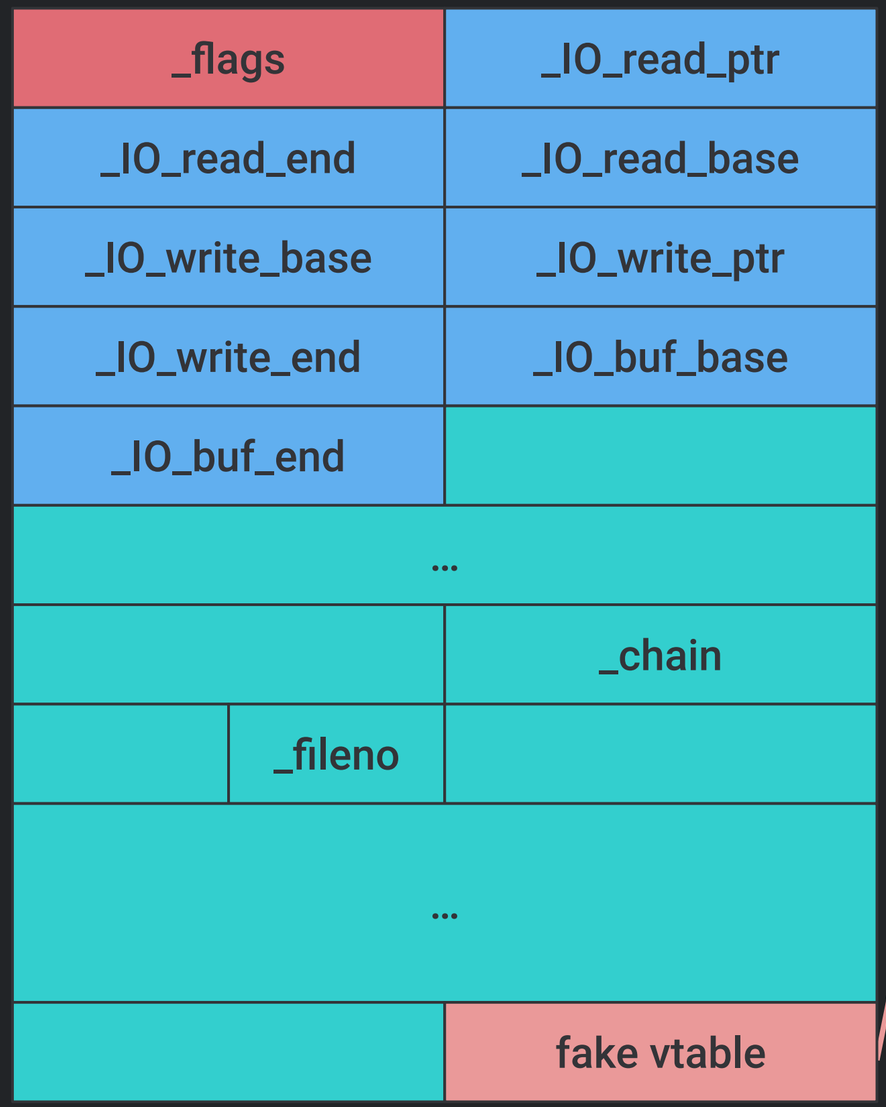


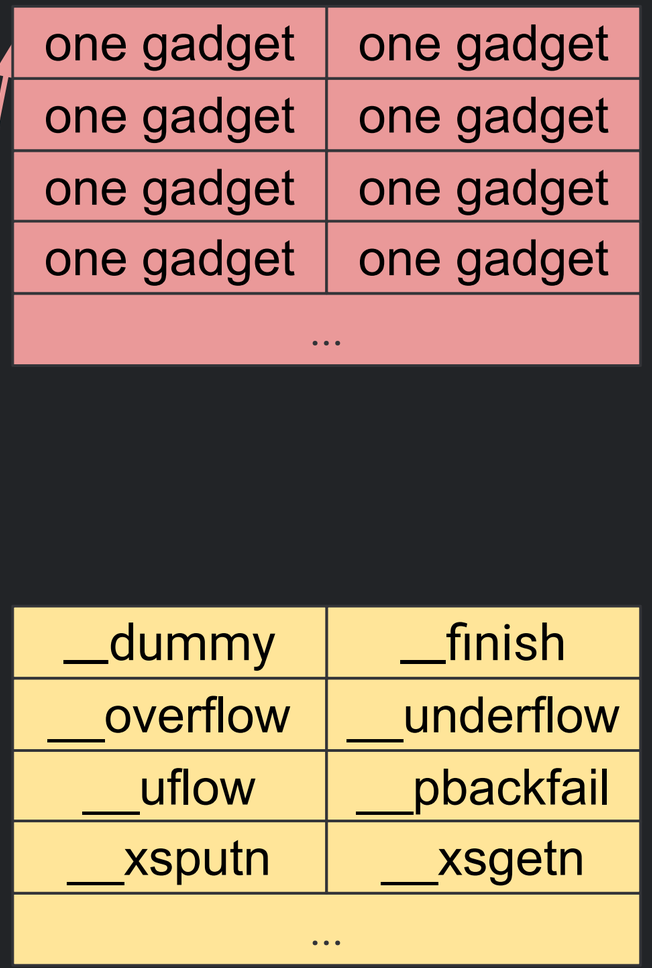


$ Hijack vtable

- 直接改 vtable pointer?
  - GLIBC 2.24 以前可以

- GLIBC 2.24 以後
  - vtable verification





$ vtable verification

- 我們是如何 call 到這些 vtable 中的 function pointer 的呢？

```
int
_IO_puts (const char *str)
{
 int result = EOF;
 size_t len = strlen (str);
 _IO_acquire_lock (stdout);

 if ((_IO_vtable_offset (stdout) != 0
      || _IO_fwide (stdout, -1) == -1)
     && _IO_sputn (stdout, str, len) == len
     && _IO_putc_unlocked ('\n', stdout) != EOF)
   result = MIN (INT_MAX, len + 1);

 _IO_release_lock (stdout);
 return result;
}
weak_alias (_IO_puts, puts)
```

$ vtable verification

- 我們是如何 call 到這些 vtable 中的 function pointer 的呢？

```
#define _IO_sputn(__fp, __s, __n) _IO_XSPUTN (__fp, __s, __n)

#define _IO_XSPUTN(FP, DATA, N) JUMP2 (__xsputn, FP, DATA, N)

#define JUMP2(FUNC, THIS, X1, X2) (_IO_JUMPS_FUNC(THIS)->FUNC) (THIS, X1, X2)

#define _IO_JUMPS_FUNC(THIS) (IO_validate_vtable (_IO_JUMPS_FILE_plus (THIS)))
```

$ vtable verification

- 檢查 vtable 是否在 GLIBC 預設的 vtable 範圍中

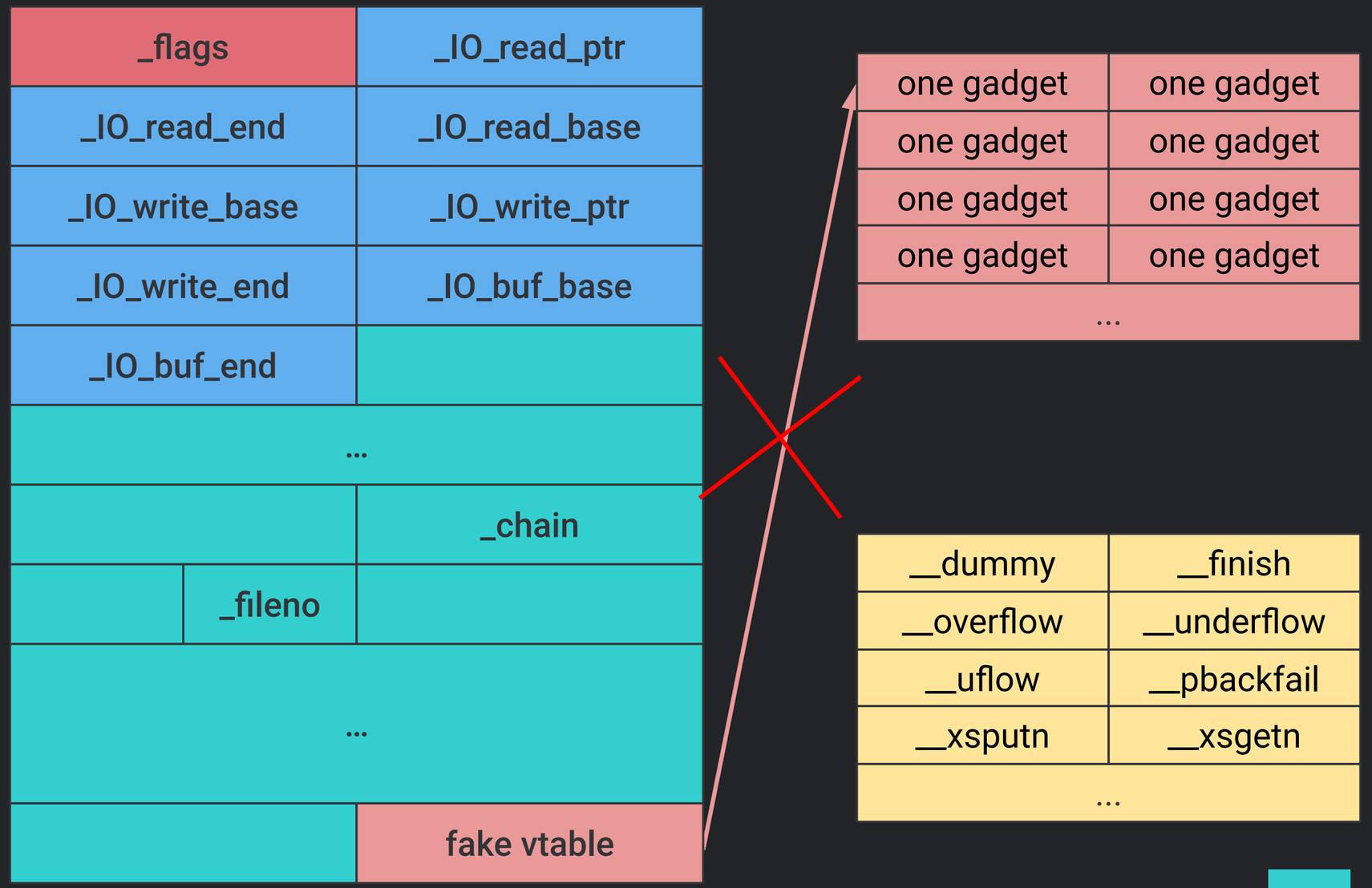
```
/* Perform vtable pointer validation.  If validation fails, terminate
  the process.  */
static inline const struct _IO_jump_t *
IO_validate_vtable (const struct _IO_jump_t *vtable)
{
 /* Fast path: The vtable pointer is within the __libc_IO_vtables
    section.  */
 uintptr_t section_length = __stop___libc_IO_vtables - __start___libc_IO_vtables;
 uintptr_t ptr = (uintptr_t) vtable;
 uintptr_t offset = ptr - (uintptr_t) __start___libc_IO_vtables;
 if (__glibc_unlikely (offset >= section_length))
   /* The vtable pointer is not in the expected section.  Use the
      slow path, which will terminate the process if necessary.  */
   _IO_vtable_check ();
 return vtable;
}
```

$ vtable verification

- Bypass?
  - 不太實際

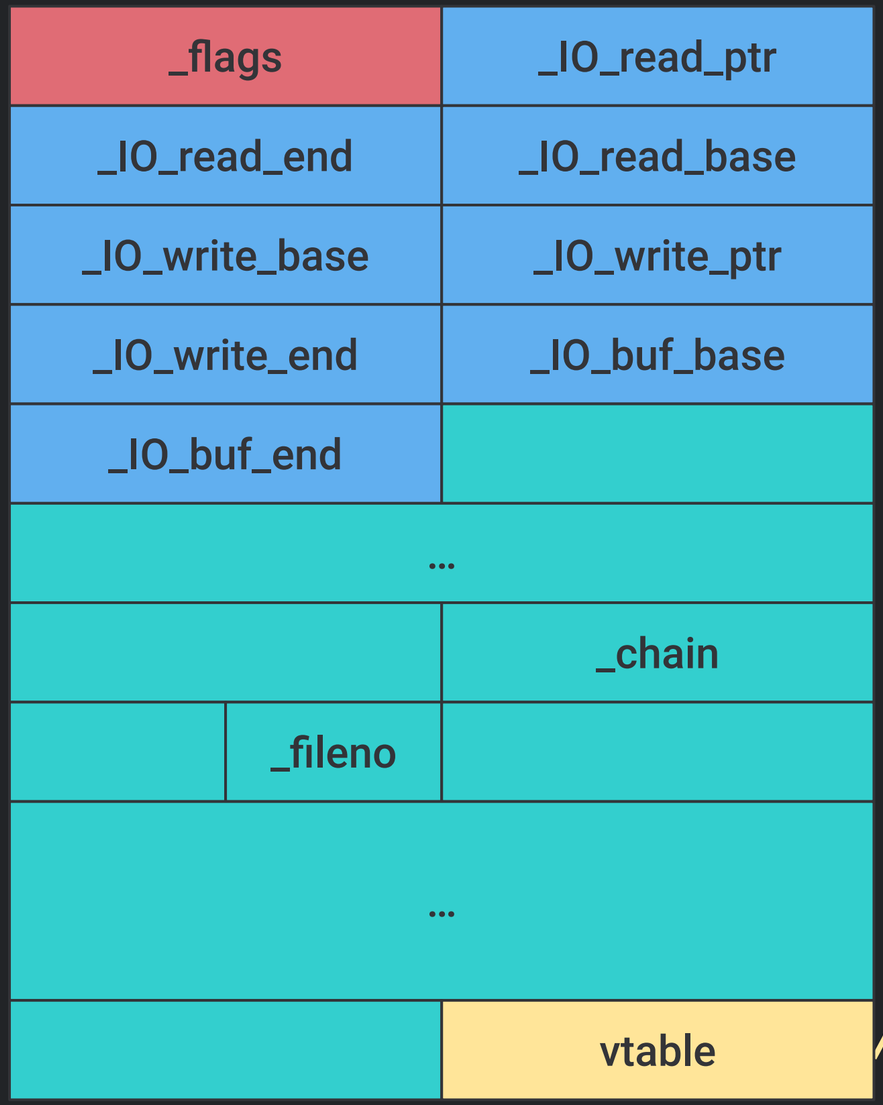
```
void attribute_hidden
_IO_vtable_check (void)
{
 void (*flag) (void) = atomic_load_relaxed (&IO_accept_foreign_vtables);
 PTR_DEMANGLE (flag);
 if (flag == &_IO_vtable_check)
   return;

 {
   Dl_info di;
   struct link_map *l;
   if (!rtld_active ()
       || (_dl_addr (_IO_vtable_check, &di, &l, NULL) != 0
           && l->l_ns != LM_ID_BASE))
     return;
 }

 __libc_fatal ("Fatal error: glibc detected an invalid stdio handle\n");
}
```

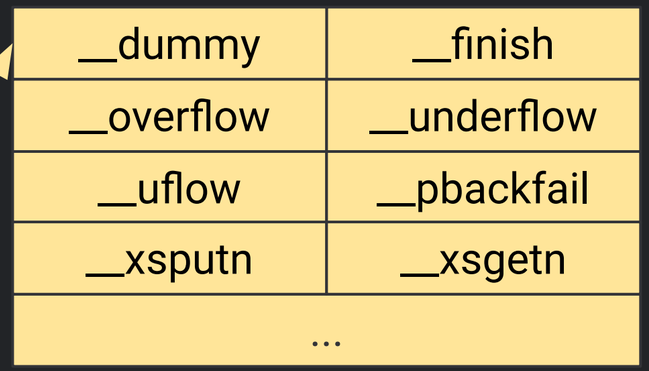
$ Hijack vtable



$ Hijack vtable

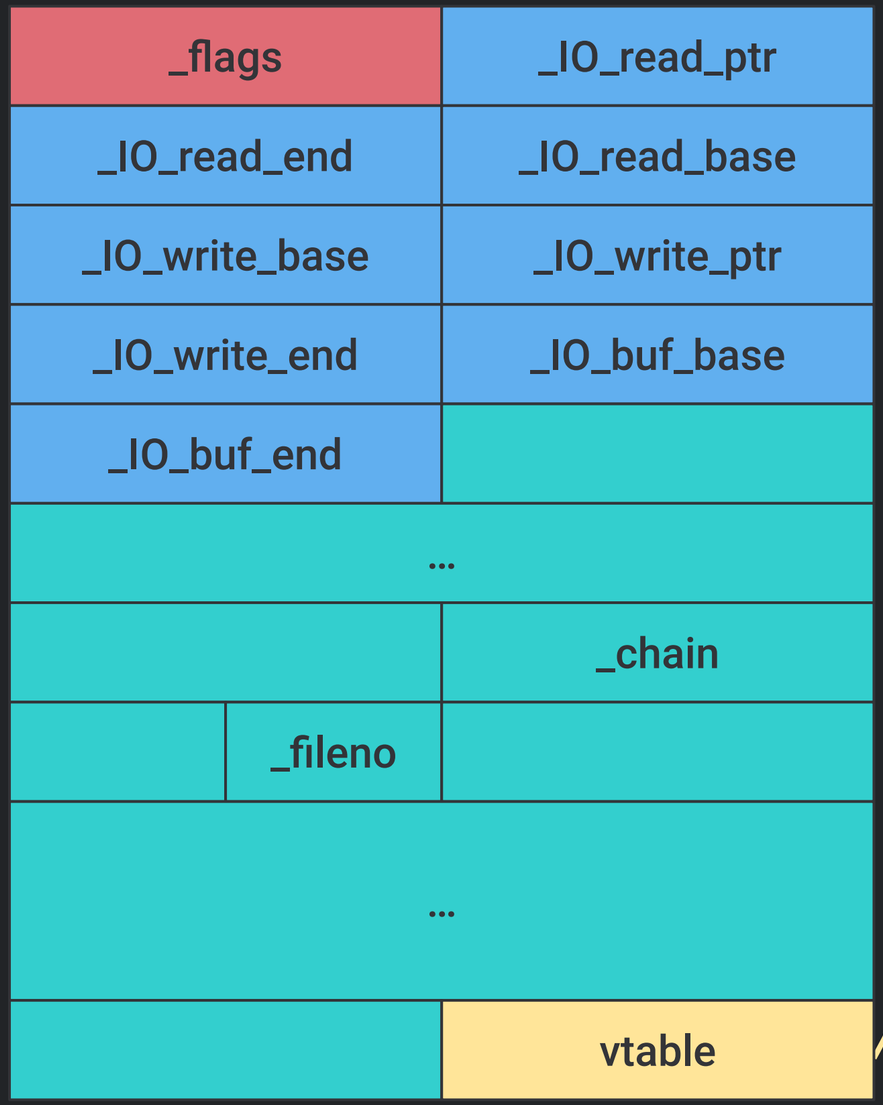
- 改 vtable 中的 pointer?

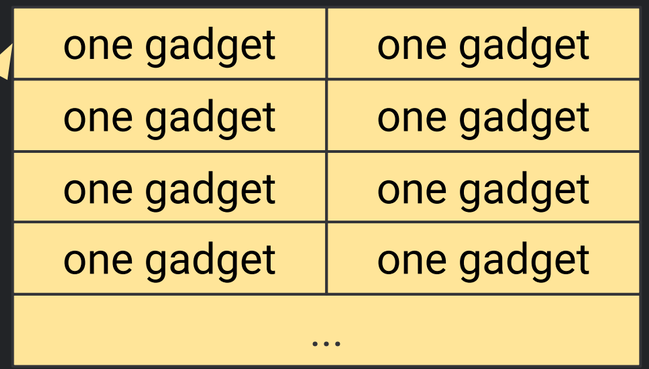




$ Hijack vtable

- 改 vtable 中的 pointer?
  - 可以
    - GLIBC 2.29 以後





$ LAB - FILE Note (X)

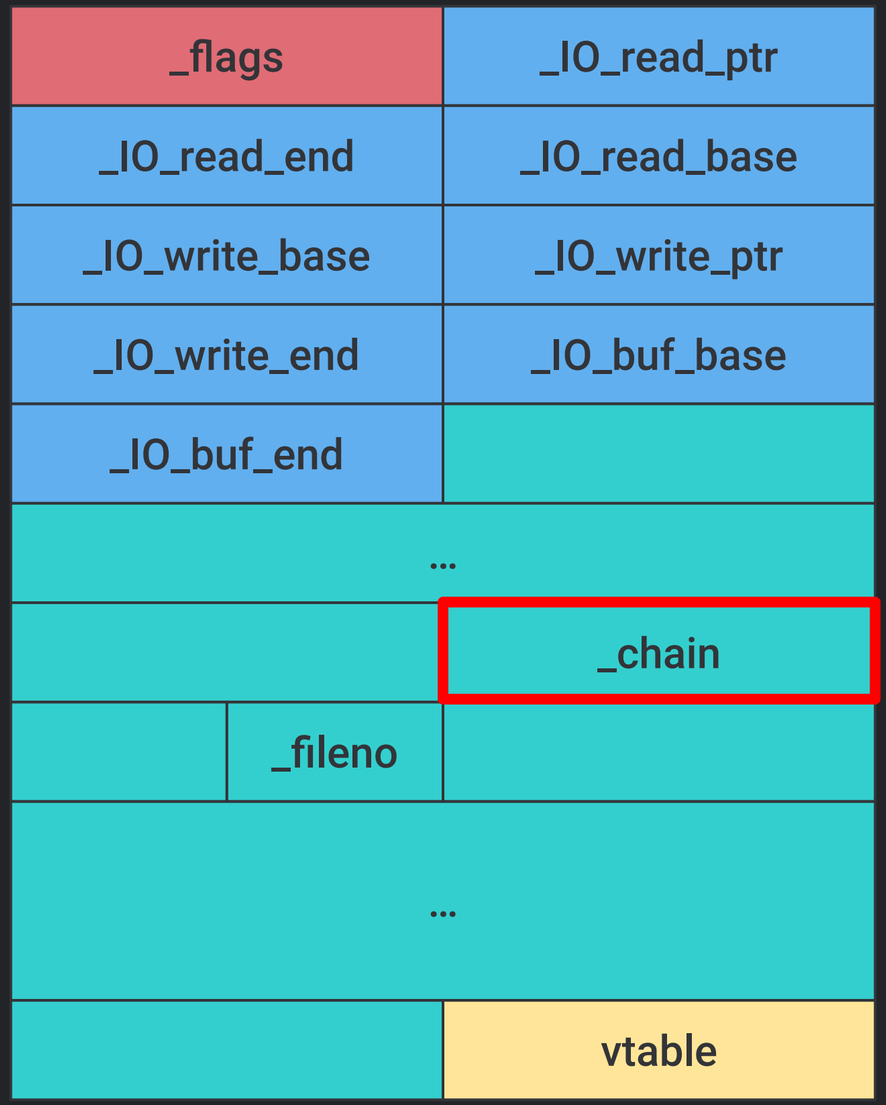
MISC

$ FSOP

- File-Stream Oriented Programming
- GLIBC version < 2.24

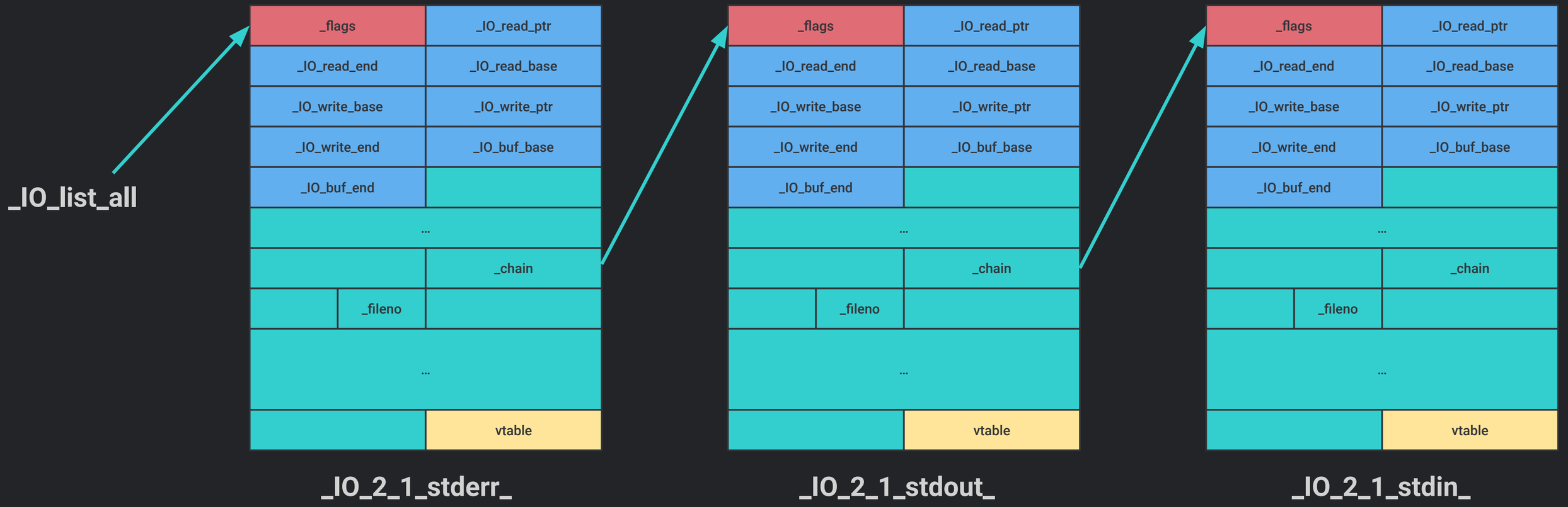
$ FSOP

- 還記得前面的 _chain 嗎?



$ FSOP

- 所有的 FILE 結構會透過 _chain 串成一個 list



$ FSOP

- 在程式結束時
  - 會 call _IO_flush_all_lockp 這個 function
    - flush _IO_list_all 這個 list

  - _IO_flush_all_lockp (libio/genops.c)

```
int
_IO_flush_all_lockp (int do_lock)
{
 int result = 0;
 FILE *fp;
 ...
 for (fp = (FILE *) _IO_list_all; fp != NULL; fp = fp->_chain)
   {
     run_fp = fp;
     ...

     if (((fp->_mode <= 0 && fp->_IO_write_ptr >
fp->_IO_write_base)
    || (_IO_vtable_offset (fp) == 0
        && fp->_mode > 0 && (fp->_wide_data->_IO_write_ptr
           > fp->_wide_data->_IO_write_base))
    )
   && _IO_OVERFLOW (fp, EOF) == EOF)
 result = EOF;

     ...
   }
 ...
}
```

$ FSOP

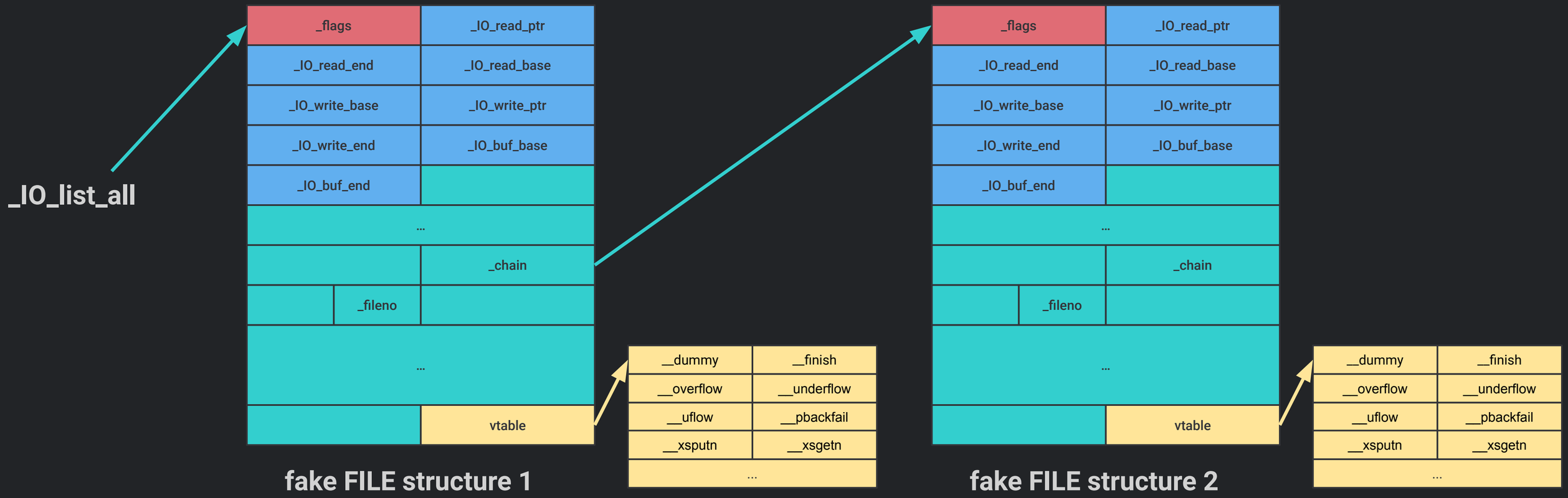
- 在程式結束時
  - 會 call _IO_flush_all_lockp 這個 function
    - flush _IO_list_all 這個 list

  - _IO_flush_all_lockp (libio/genops.c)

```
int
_IO_flush_all_lockp (int do_lock)
{
 int result = 0;
 FILE *fp;

 for (fp = (FILE *) _IO_list_all; fp != NULL; fp = fp->_chain)
   {
     run_fp = fp;
     ...

     if (((fp->_mode <= 0 && fp->_IO_write_ptr >
fp->_IO_write_base)
    || (_IO_vtable_offset (fp) == 0
        && fp->_mode > 0 && (fp->_wide_data->_IO_write_ptr
           > fp->_wide_data->_IO_write_base))
    )
   && _IO_OVERFLOW (fp, EOF) == EOF)
 result = EOF;

     ...
   }
 ...
}
```

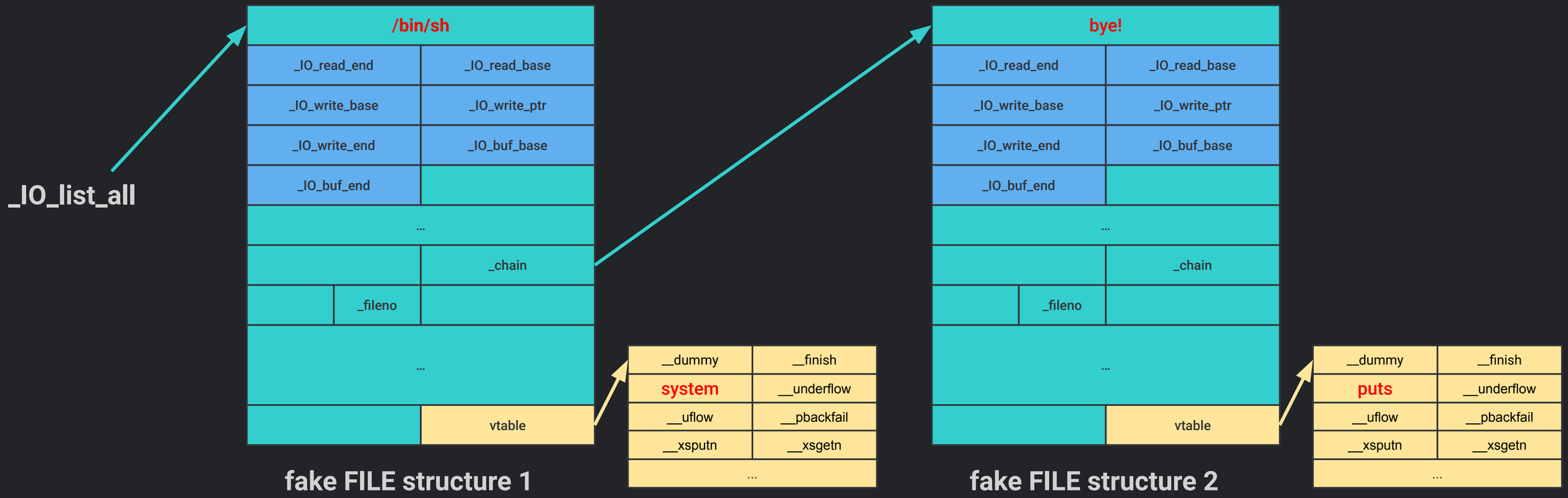
$ FSOP

- 將 _IO_list_all 改成偽造的結構



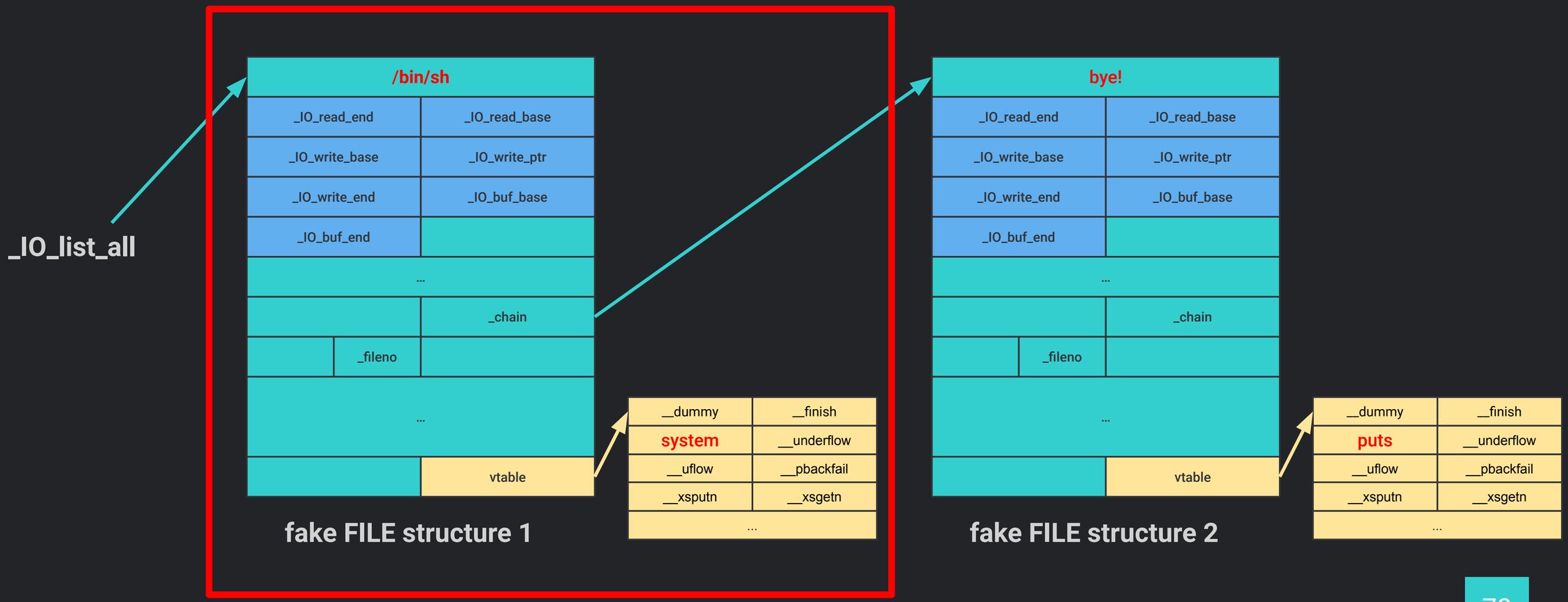
$ FSOP

- 將 _IO_list_all 改成偽造的結構



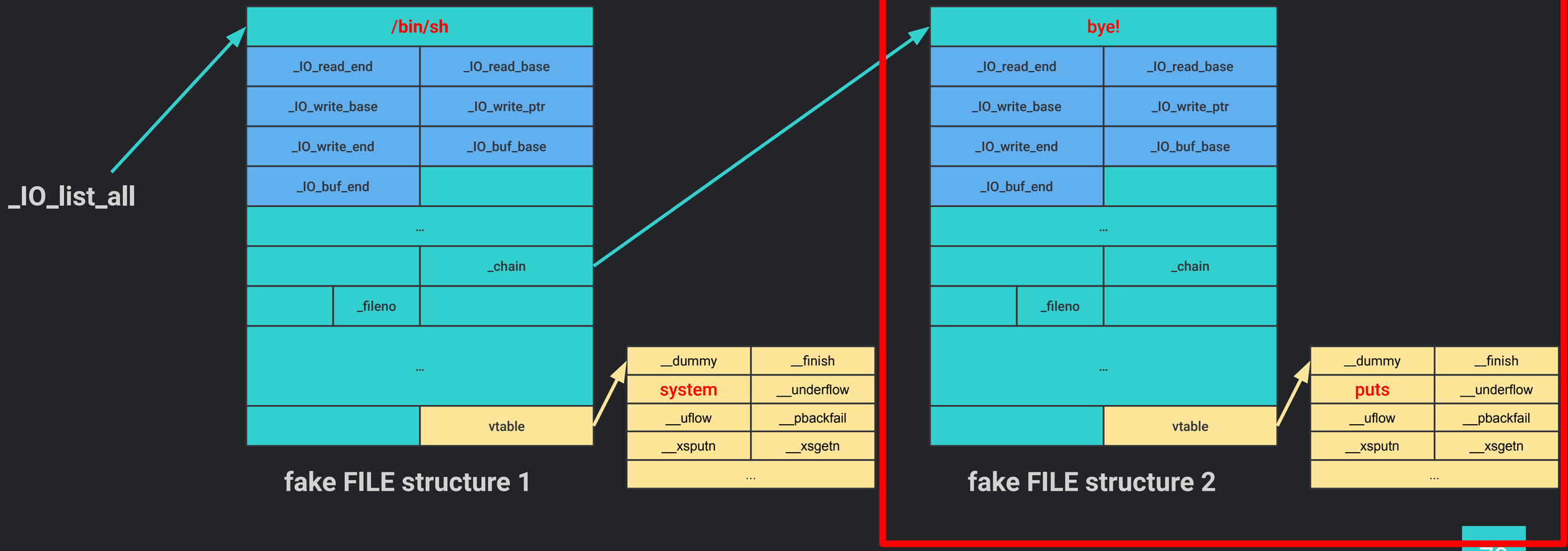
$ FSOP

- 將 _IO_list_all 改成偽造的結構



$ FSOP

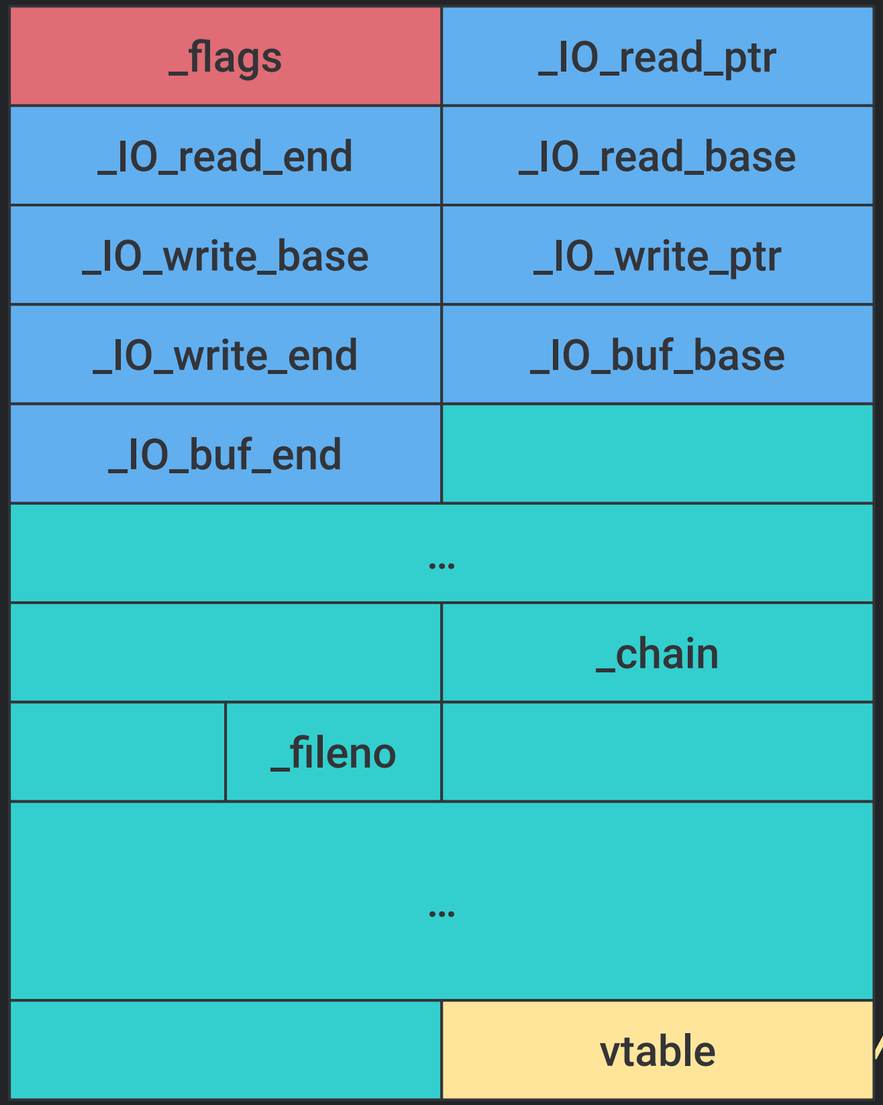
- 將 _IO_list_all 改成偽造的結構

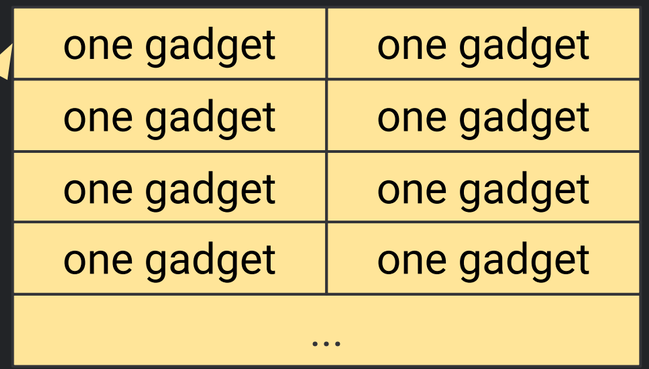


$ _IO_str_jumps vtable

- 不能自己偽造 vtable
- 改不到 vtable entry

- 利用既有的 vtable
  - _IO_str_jump





$ _IO_str_jumps vtable

- GLIBC < 2.28
- _IO_strfile_ 這個結構所用的 vtable
- 結構裡面有 function pointer

```
typedef struct _IO_strfile_
{
 struct _IO_streambuf _sbf;
 struct _IO_str_fields _s;
} _IO_strfile;

struct _IO_str_fields
{
 _IO_alloc_type _allocate_buffer;
 _IO_free_type _free_buffer;
};

typedef void *(*_IO_alloc_type) (_IO_size_t);
typedef void (*_IO_free_type) (void*);
```

$ _IO_str_jumps vtable

- GLIBC < 2.28
- _IO_strfile_ 這個結構所用的 vtable
- vtable 中的 function 會去用到結構中的 function pointer

```
void
_IO_wstr_finish (_IO_FILE *fp, int dummy)
{
 if (fp->_wide_data->_IO_buf_base && !(fp->_flags2 & _IO_FLAGS2_USER_WBUF))
   (((_IO_strfile *) fp)->_s._free_buffer) (fp->_wide_data->_IO_buf_base);
 fp->_wide_data->_IO_buf_base = NULL;

 _IO_wdefault_finish (fp, 0);
}
```

$ _IO_str_jumps vtable

- GLIBC < 2.28
- Exploit
  - 把 vtable 改到 _IO_str_jumps
  - 偽造結構中的 function pointer

```
void
_IO_wstr_finish (_IO_FILE *fp, int dummy)
{
 if (fp->_wide_data->_IO_buf_base && !(fp->_flags2 & _IO_FLAGS2_USER_WBUF))
   (((_IO_strfile *) fp)->_s._free_buffer) (fp->_wide_data->_IO_buf_base);
 fp->_wide_data->_IO_buf_base = NULL;

 _IO_wdefault_finish (fp, 0);
}
```

$ HW - FILE Note

THANK YOU FOR LISTENING!

ANY QUESTIONS?