Memory allocation

Luca Tornatore - I.N.A.F.

“Foundation of HPC” course

DATA SCIENCE &
SCIENTIFIC COMPUTING

2021-2022 @ Università di Trieste

Outline

Memory Padding

Overhead of Memory Allocation

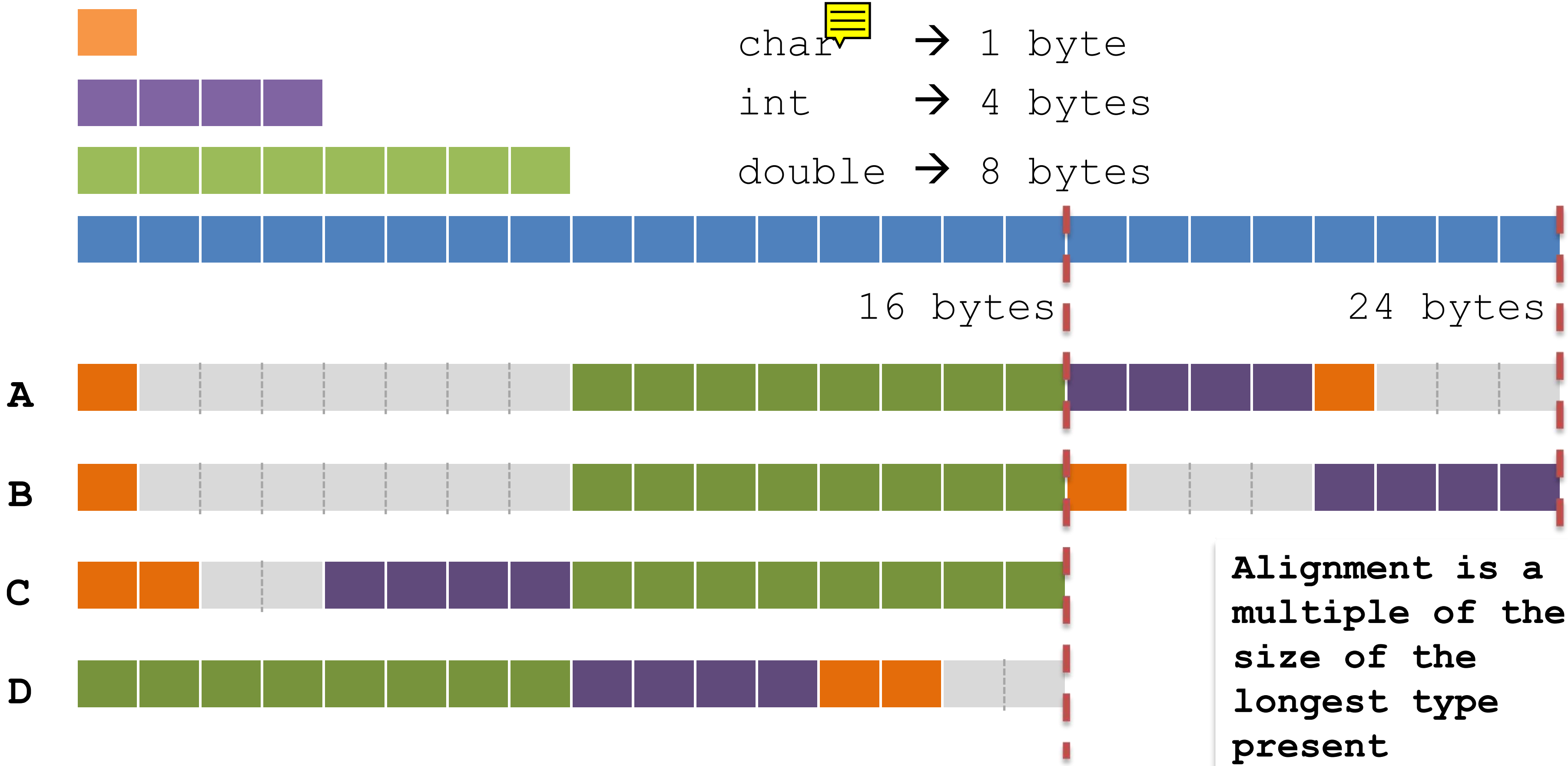
Memory allocation has a memory cost

```c
typedef struct
{
  char      char_field;
  double    double_field;
  int       int_field;
  char      char_field2;
} STRUCT_A;

typedef struct
{
  char      char_field;
  double    double_field;
  char      char_field2;
  int       int_field;
} STRUCT_B;
```

```c
typedef struct
{
  char      char_field;
  char      char_field2;
  int       int_field;
  double    double_field;
} STRUCT_C;

typedef struct
{
  double    double_field;
  int       int_field;
  char      char_field;
  char      char_field2;
} STRUCT_D;
```

Is there any difference among the above C structures ?

Memory allocation has a memory cost : padding



Alignment is a multiple of the size of the longest type present

Memory allocation has a memory cost : padding

`gcc … -fpack_struct[=n]`

An instruction to pack them all an in the bitfield chain them down.
To be used carefully: it generates code *binary-incompatible* with code generated without the option (offset are different) **and** *sub-optimal* code.
Normally used for non-default binary interface (reduces the data stream).
If given, n must be a (small) power of two.

`__attribute__ ((packed));`

Inline in the structure definition, at each field you want not to waste any byte.
The same words of caution than above hold.

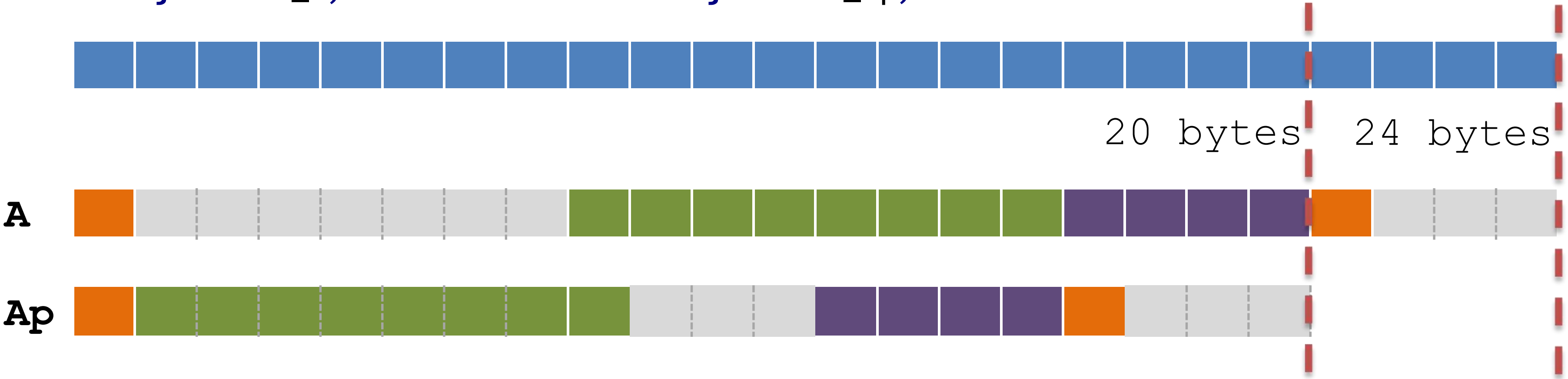
```c
typedef struct
{
  char    char_field;
  double  double_field;
  int     int_field;
  char    char_field2;
} STRUCT_A;
```

```c
typedef struct
{
  char    char_field;
  double  double_field __attribute__ ((packed));
  int     int_field;
  char    char_field2;
} STRUCT_Ap;
```

Memory allocation has a memory cost : padding

```c
typedef struct
{
  char    char_field;
  double  double_field;
  int     int_field;
  char    char_field2;
} STRUCT_A;
```

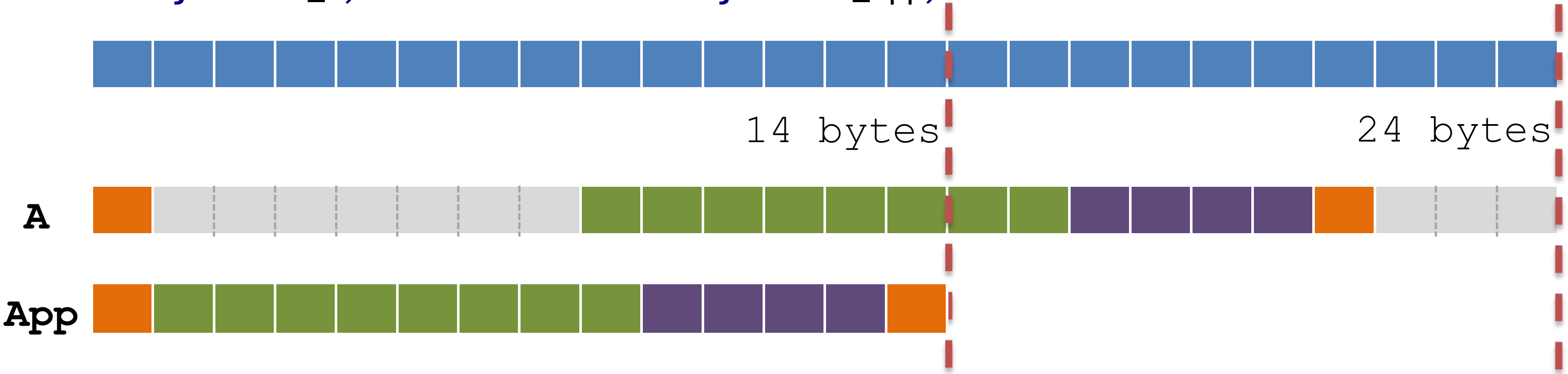
```c
typedef struct
{
  char    char_field;
  double  double_field __attribute__ ((packed));
  int     int_field;
  char    char_field2;
} STRUCT_Ap;
```



Memory allocation has a memory cost : padding

```c
typedef struct
{
  char    char_field;
  double  double_field;
  int     int_field;
  char    char_field2;
} STRUCT_A;
```

```c
typedef struct
{
  char    char_field;
  double  double_field __attribute__ ((packed));
  int     int_field  __attribute__ ((packed));
  char    char_field2;
} STRUCT_App;
```



SCO/examples_on_memory_allocation/structure_padding.c

Memory allocation has a memory cost : padding

General remark:

in order to have best memory access performances, it is usually better to have data aligned to the natural alignment of your machine, which typically is 64 bits.

```
__attribute__ ((aligned (n)));
```

You may achieve this in your data structures by using

Memory allocation has a memory cost : padding

System's `malloc()` allocator returns memory addresses multiples of `8` or `16` for `32-` and `64-bits` systems.

If you different needs (for instance: using `AVX`*N* instructions), you can use special calls:

```
void * posix_memalign (void **memptr, size_t alignment, size_t size)

void * aligned_alloc (size_t alignment, size_t size)
```

introduced in ISO C11 and hence may have better portability to non-POSIX systems

Outline

Overhead of
Memory Allocation

Memory allocation has a memory cost

Everytime you allocate some memory chunk on the heap, the system has to keep track of it, in order to

- maintain a precise account of used and available memory
- be able to "register back" that chunk into the free memory when you don't need it anymore (you `free()` it).

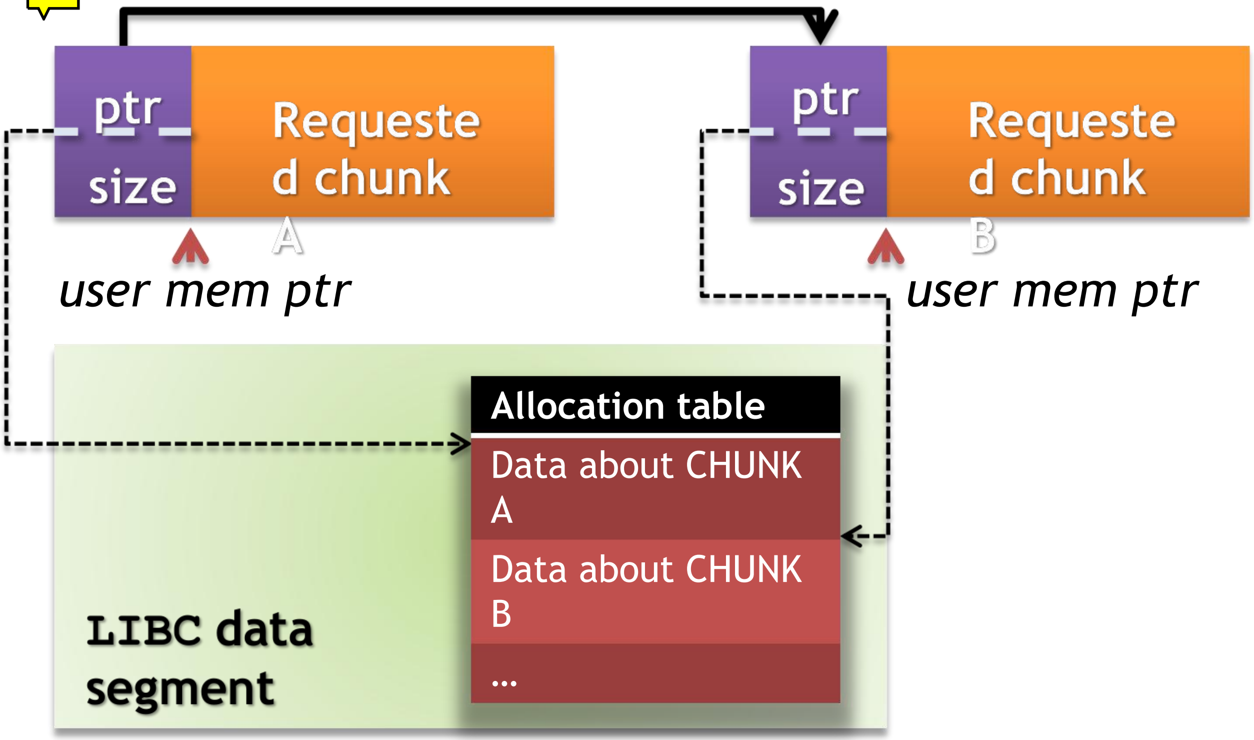
So, in addition to allocate *padded* memory layouts, which amounts to consume more memory than you formally request, there is also an additional "administrative" overhead whose amount is strongly system- and implementation-dependent (normally few bytes).

Memory allocation has a memory cost

`LIBC` prepends an header to the chunk of data it allocates upon your request.

In that header, whose dimension is implementation-dependent, there are several data it uses to check the consistency of memory chain and to recover the data about that same allocation.

Every detail is strongly implementation-dependent !



Memory allocation has a memory cost

Allocating a huge amount of small data (like in text-book linked-list techniques) might be not the optimal strategy:

- you incur in some waste of memory due to padding, depending on the layout of data;
- for sure in a larger amount of data needed to trace every chunk you require.

How much large is the latter overhead ?
Again, that is implementation-dependent.

Let's measure it on your computer and for different implementation
(i.e. different compilers and libc)

# of allocated blocks	Requested Mem	AdditionallyAllocated	Ptr Overhead	System overhead
10M	400 MB	24 %	80 MB	18 %
1M	400 MB	1.3 %	8 MB	3.2 %
100k	400 MB	0.09 %	0.8 MB	0.27 %
10k	400 MB	0.0 %	80 K	0.05%
1k	400 MB	0.12 %	8 K	0.125 %
100	400 MB	0.033 %	0.8 K	0.034 %
10	400 MB	0.006 %	0.1 K	0.006 %