Memory allocation

Luca Tornatore - I.N.A.F.

"Foundation of HPC" course

DATA SCIENCE & SCIENTIFIC COMPUTING

2019-2020 @ 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;
```

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

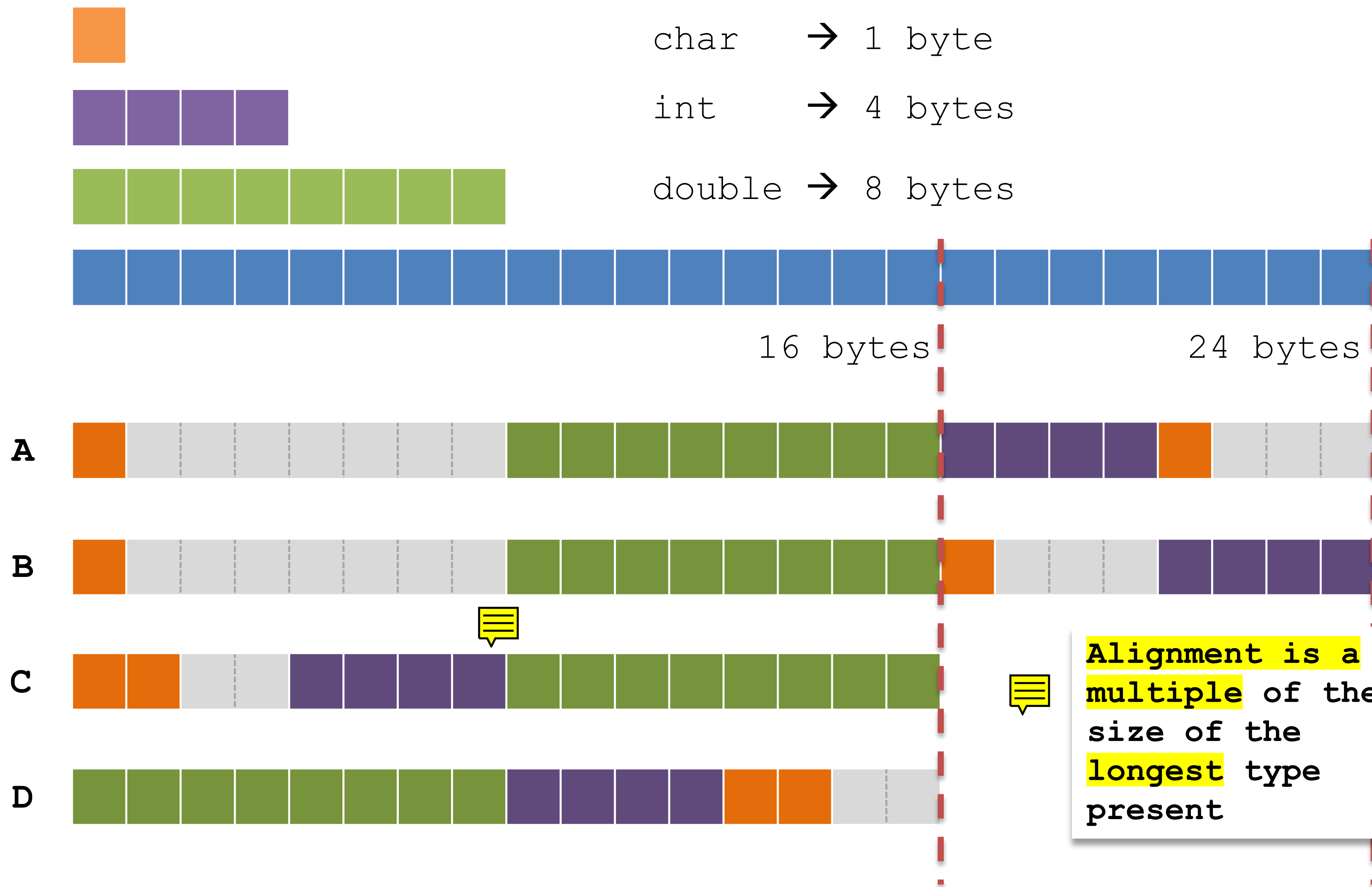
```c
typedef struct
{
 char      char_field;
 double  double_field;
 char      char_field2;
 int         int_field;
} STRUCT_B;
```

```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 ?

➔ …just have a look at the live results..

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.

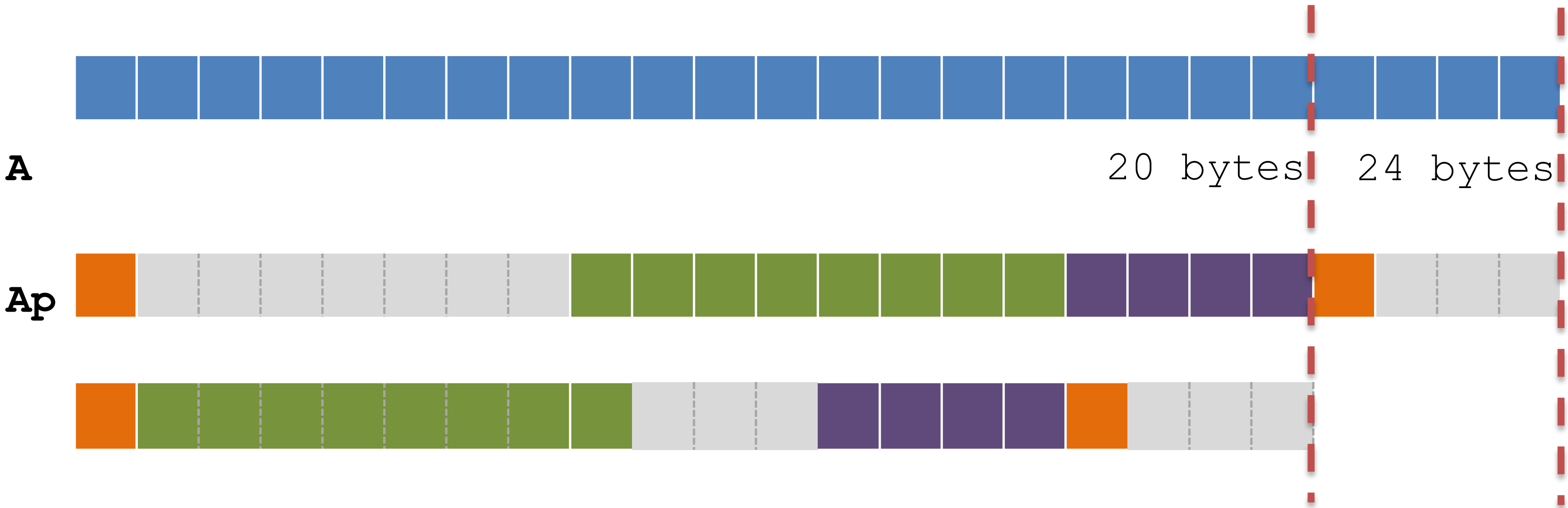
```
typedef struct
{
 char    char_field;
 double  double_field;
 int     int_field;
 char    char_field2;
} STRUCT_A;
```

```
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

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

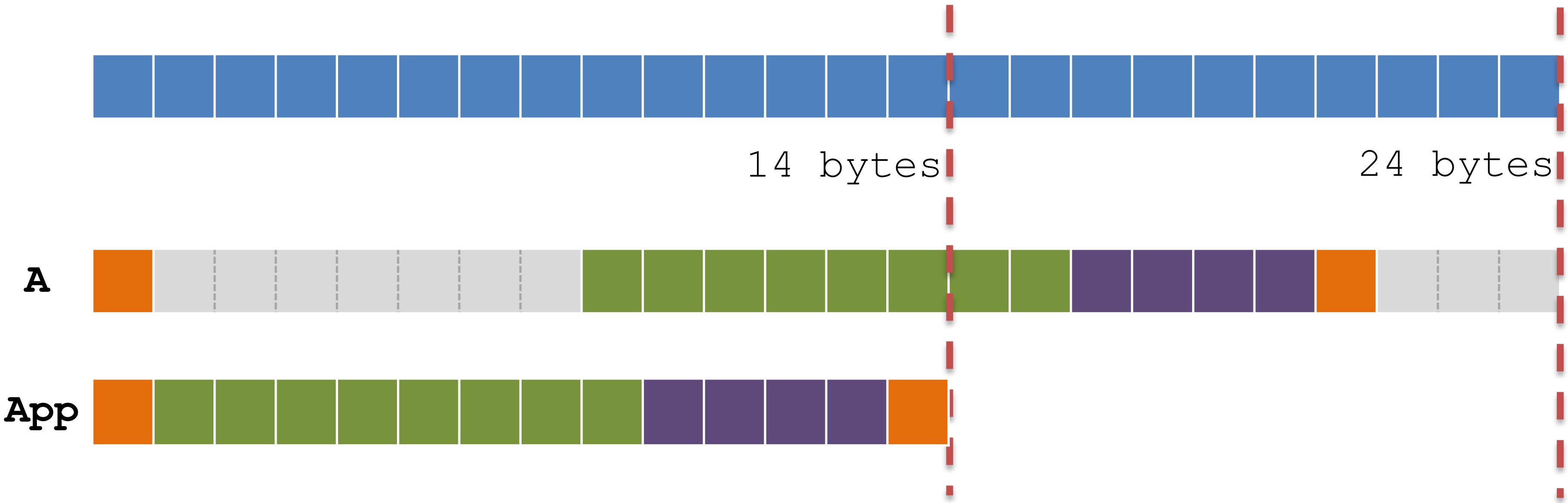
```
typedef struct
{
  char    char_field;
  double  double_field __attribute__ ((packed));
  int     int_field;
  char    char_field2;
} STRUCT_Ap;
```



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;
```



➔ …just have a look at the live results..

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 32 or 64 bits.

You may achieve this in your data structures by using

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

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

POINTER SIZE:32 bit systen

Overhead of
Memory Allocation

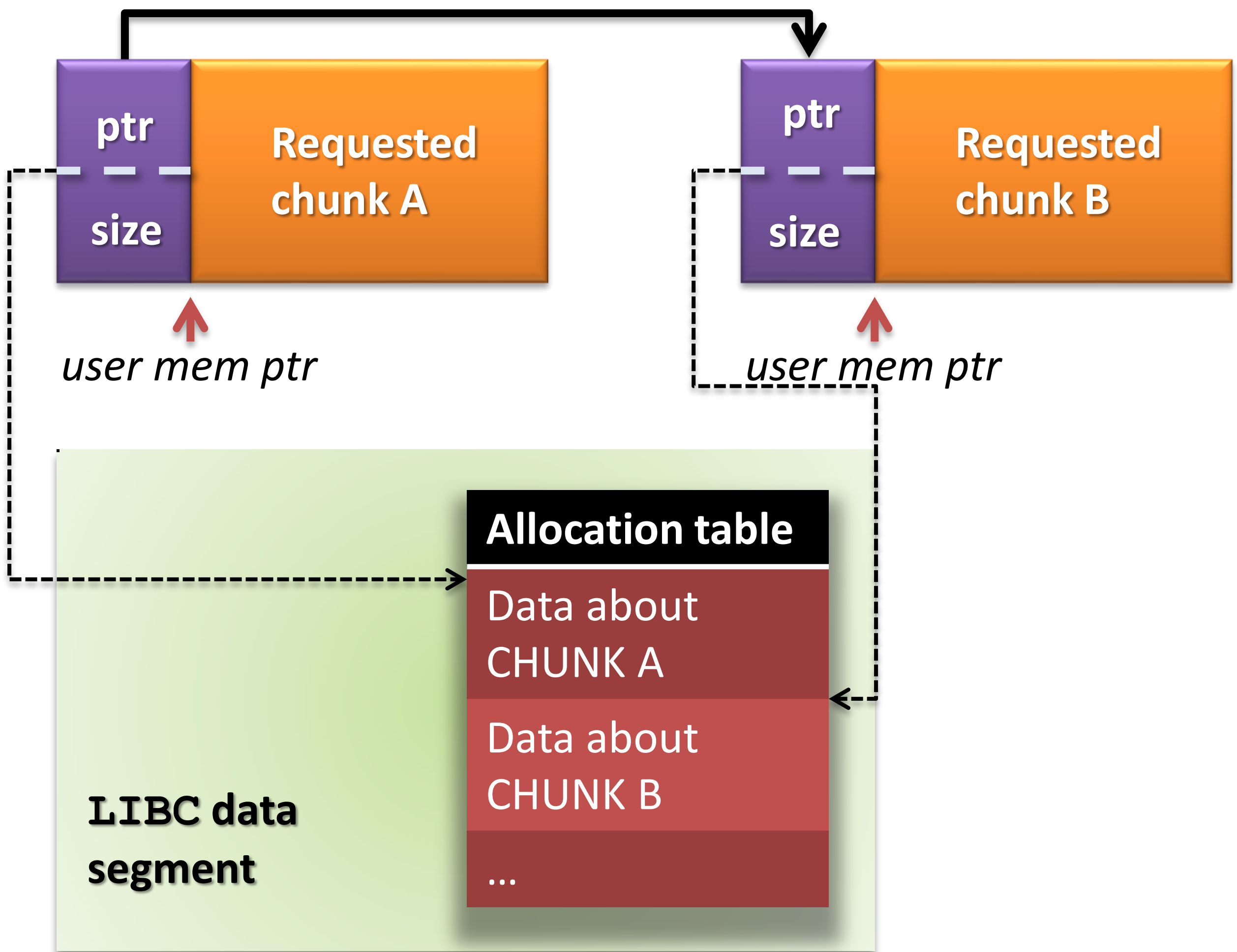
Memory allocation has a memory cost

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.

Memory allocation has a memory cost

Allocating a huge amount of small data (like in classic 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)*

➔ …just have a look at the live results..

	Requested Mem	Additionally Allocated	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 %