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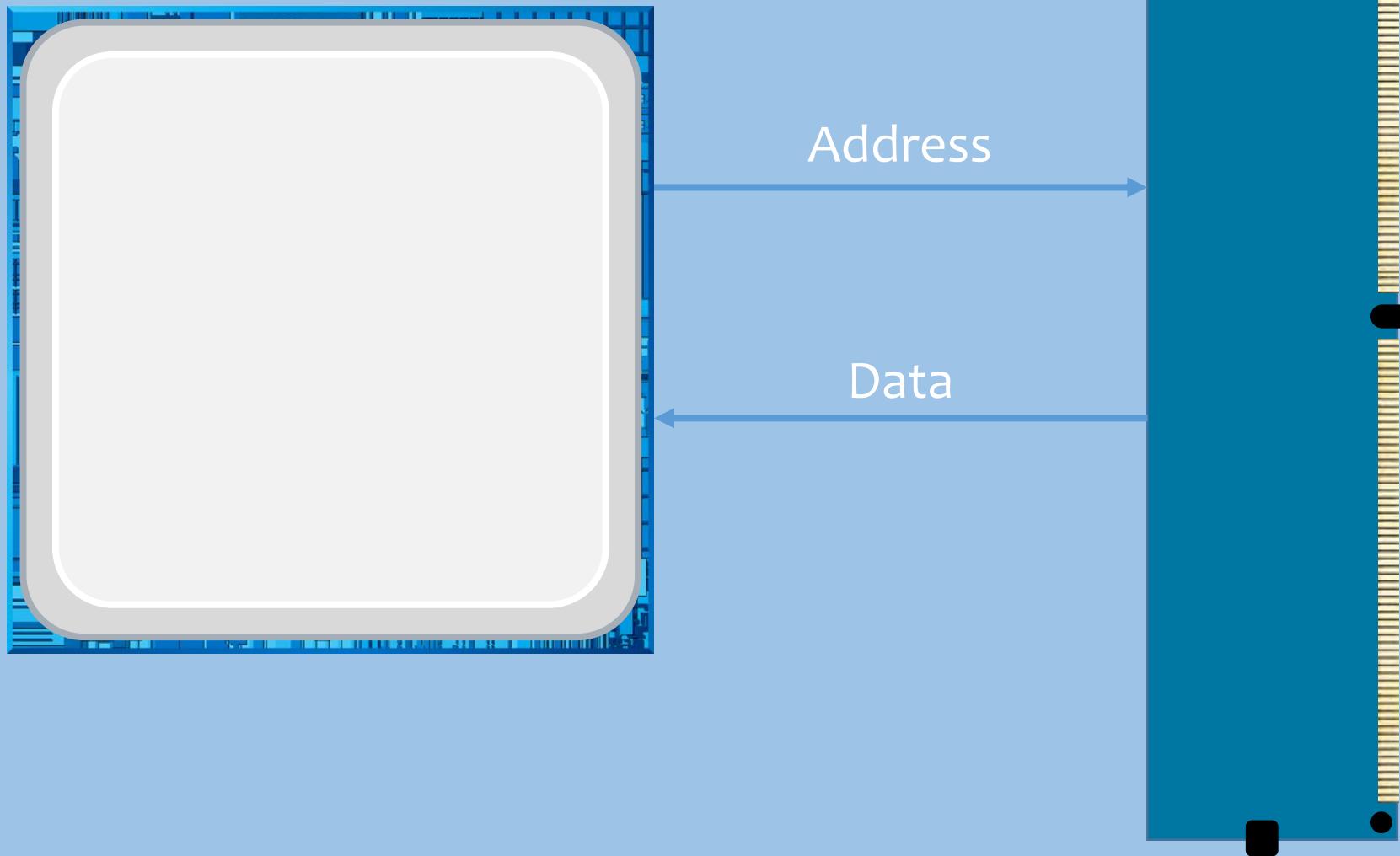
Memory Allocation

① ?

② ?

③ ?

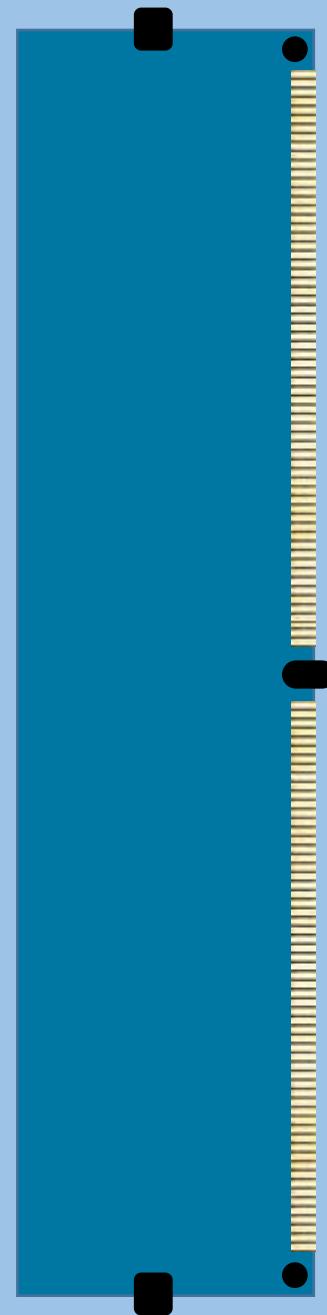
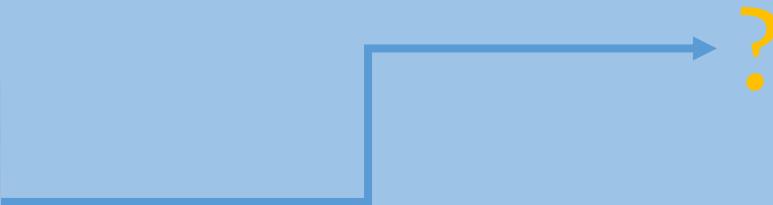
Physical Address



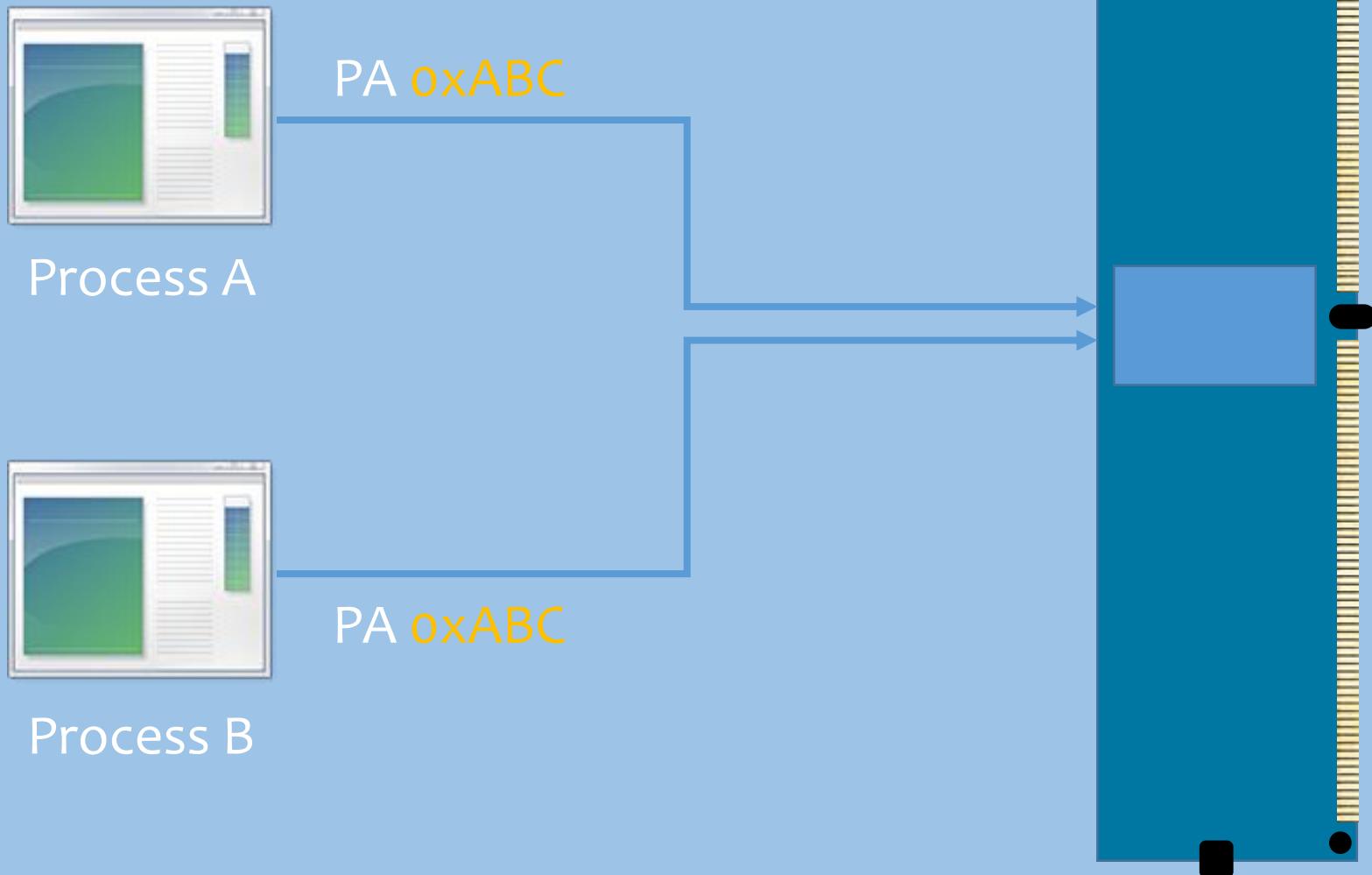
Problem



Process A



Problem



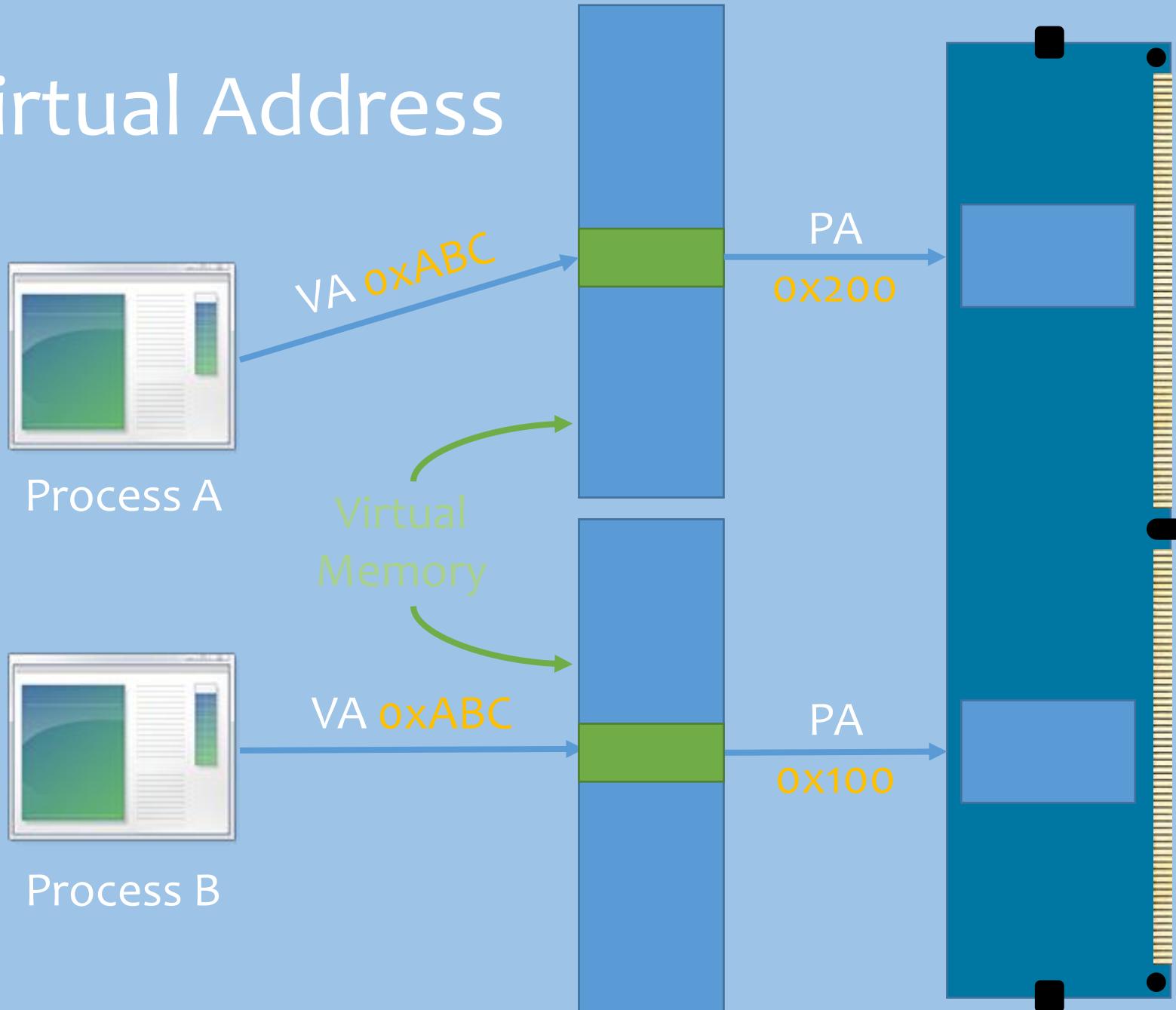


David John Wheeler

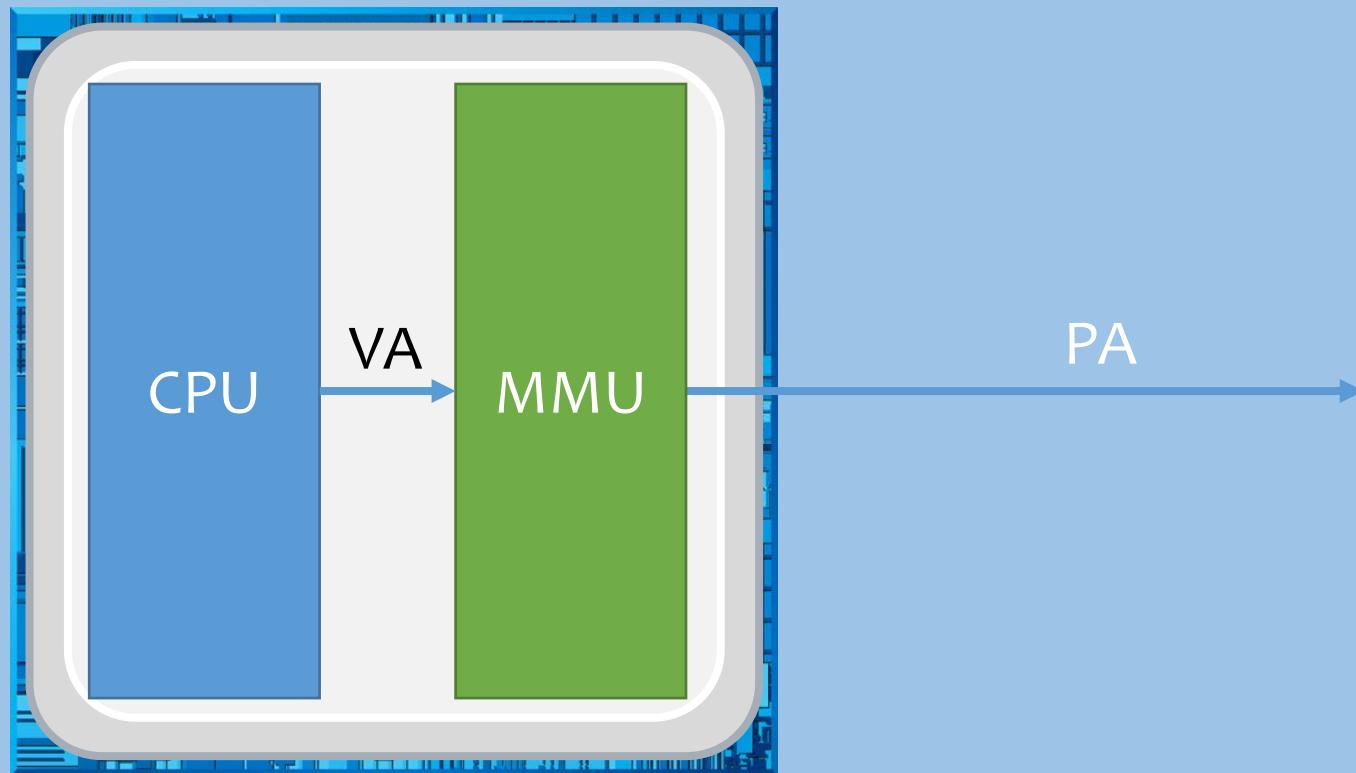
1985 Computer Pioneer Award
for assembly language programming

“ All problems in computer science can be solved by another level of indirection ... except of course for the problem of too many indirections. ”

Virtual Address



Memory Management Unit

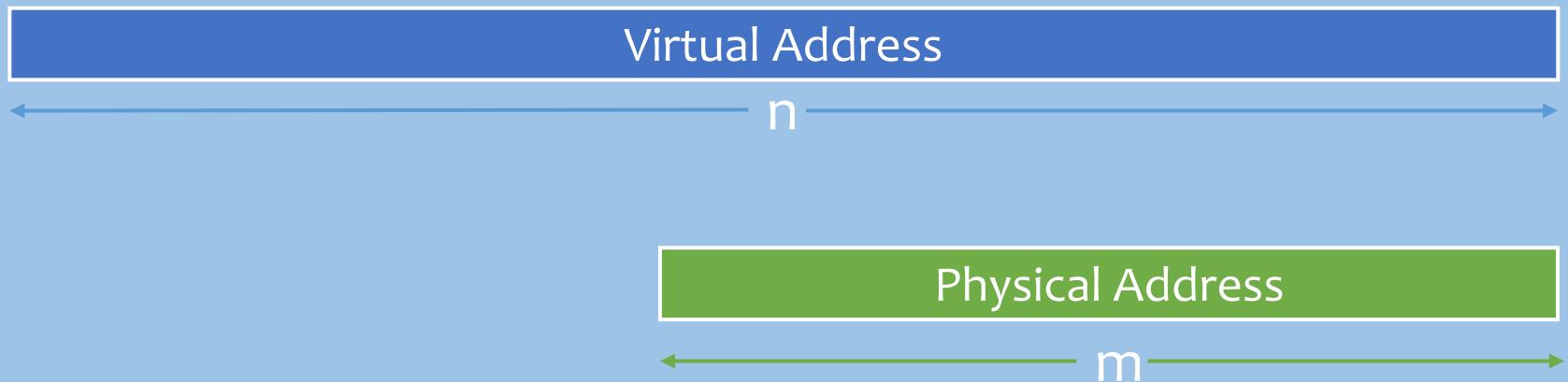


Address Space

Virtual Address Space
 $\{0,1,\dots,N - 1\}$

>>>

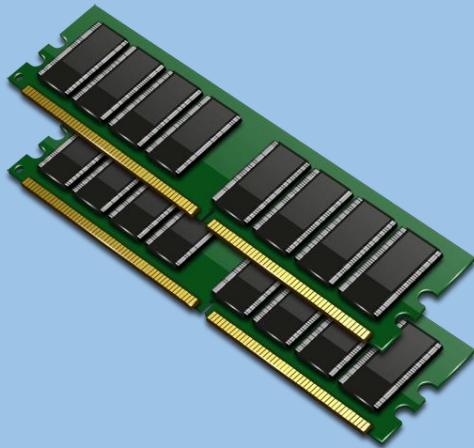
Physical Address Space
 $\{0,1,\dots,M - 1\}$



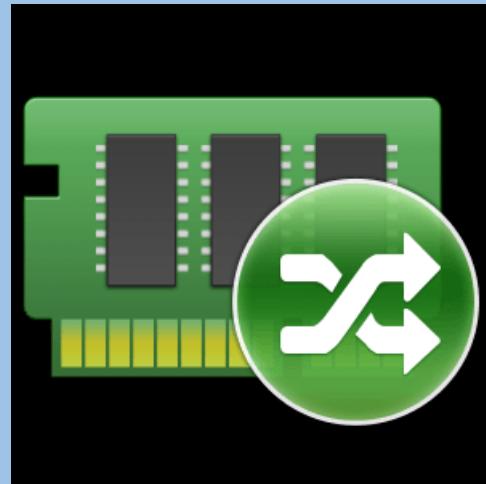
Virtual Address

Number of virtual address bits (n)	Number of virtual addresses (N)	Largest possible virtual address
8	$2^8 = 256$	$2^8 - 1 = 255$
	$2^7 = 64K$	$2^{32} - 1 = ?G - 1$
	$2^8 = 256T$	
64		

Why Virtual Memory?



Efficiency



Simplification

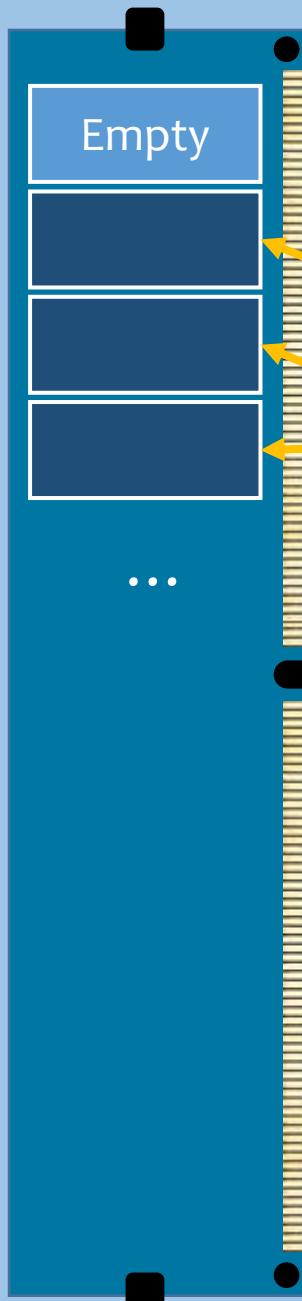


Protection

Organization

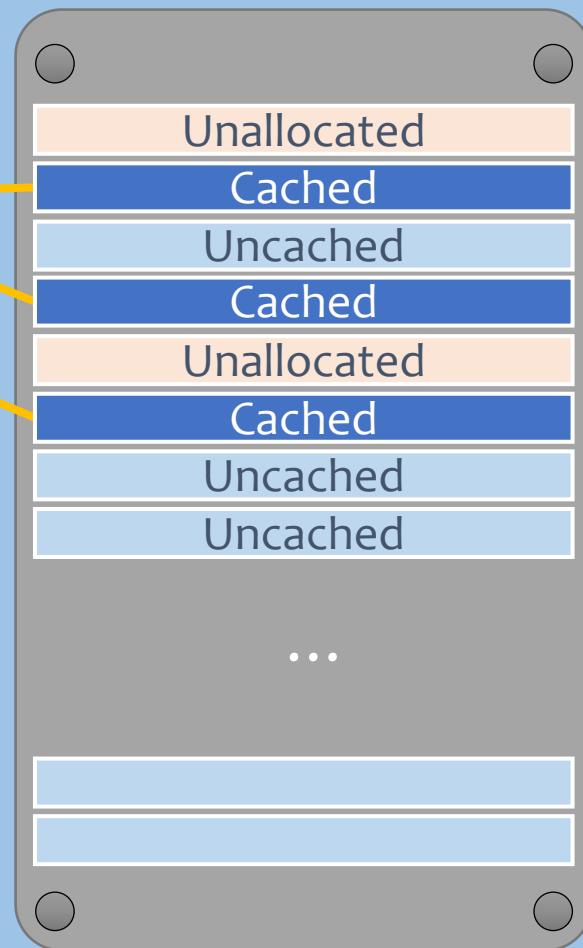
Physical pages

0
1
2
3



Disk

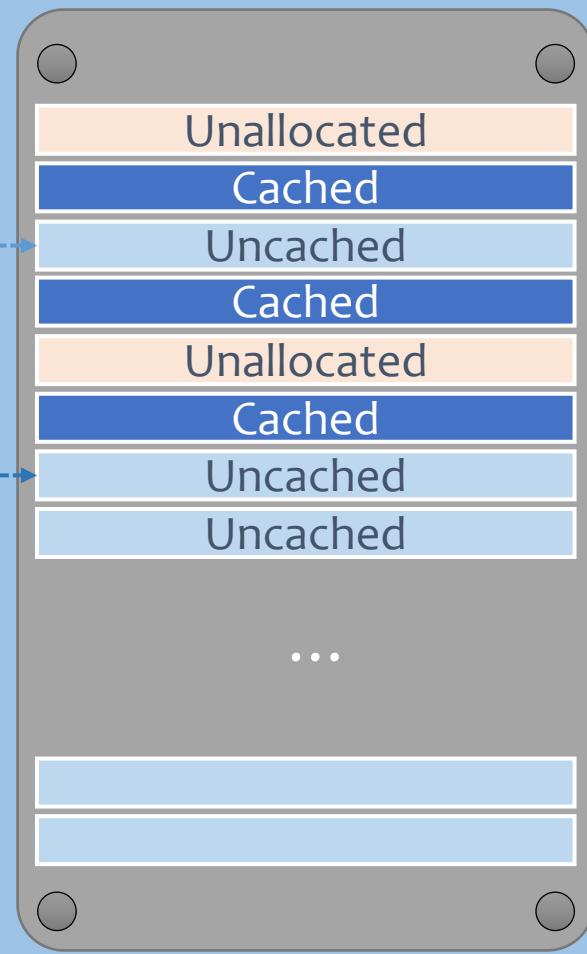
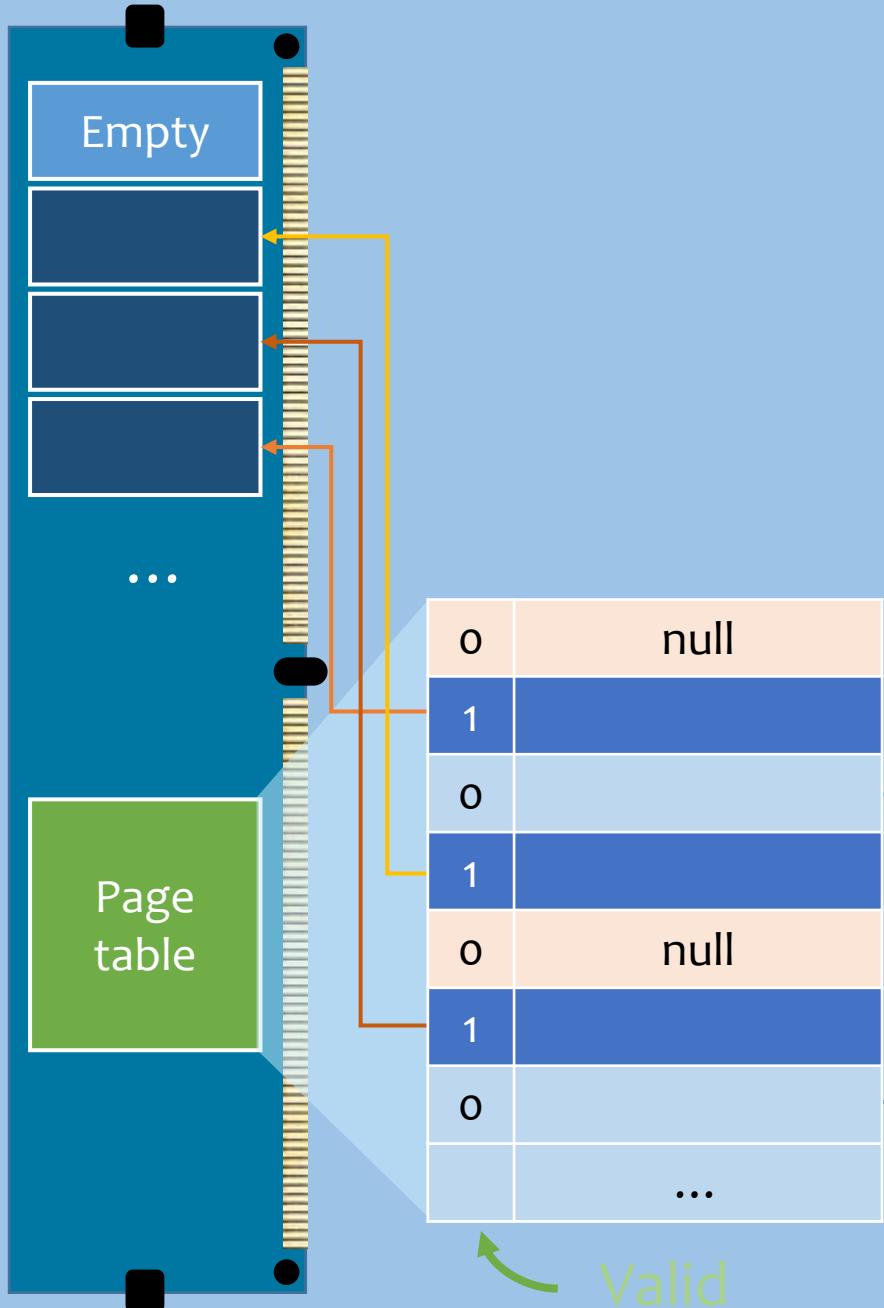
0
1
2
3



Virtual pages

Page table

Physical pages



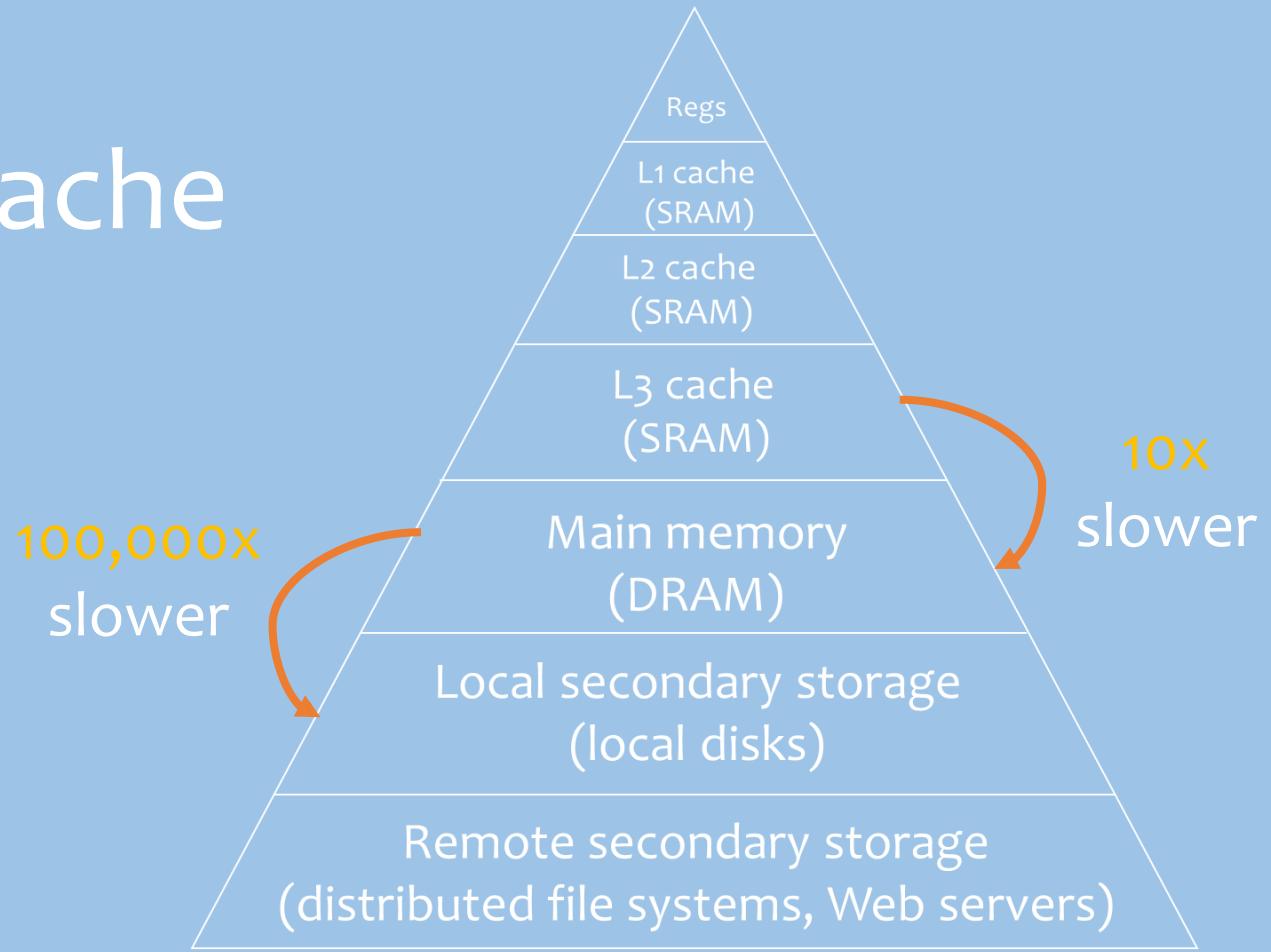
Virtual pages

0
1
2
3

Page Table Entries

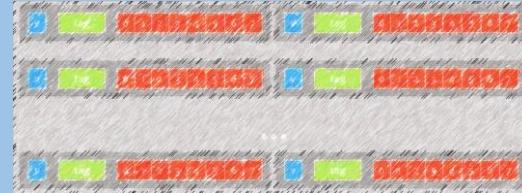
n	P=2 ^p	Number of PTEs
16	4K	
16	8K	
32	4K	
32	8K	

DRAM Cache



①

Large Page



② Fully Associative

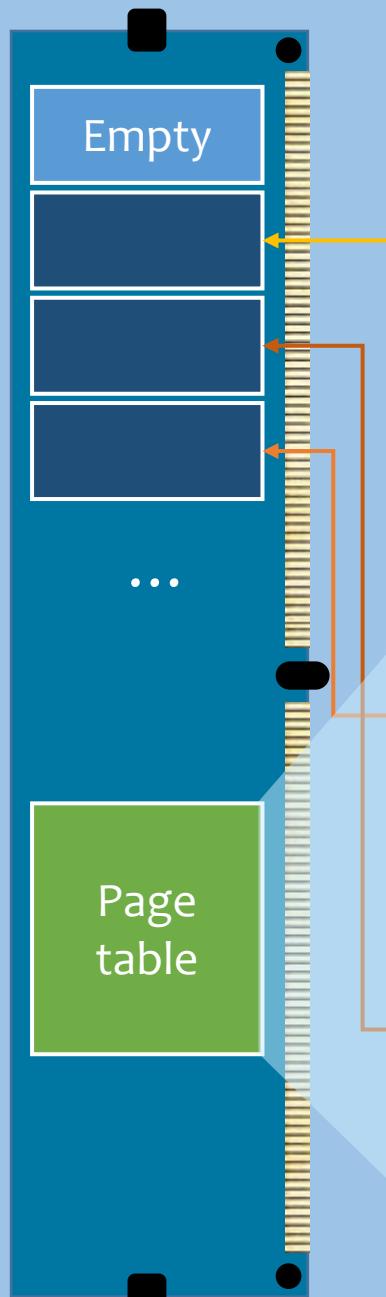


③ Write-back

Allocating Pages

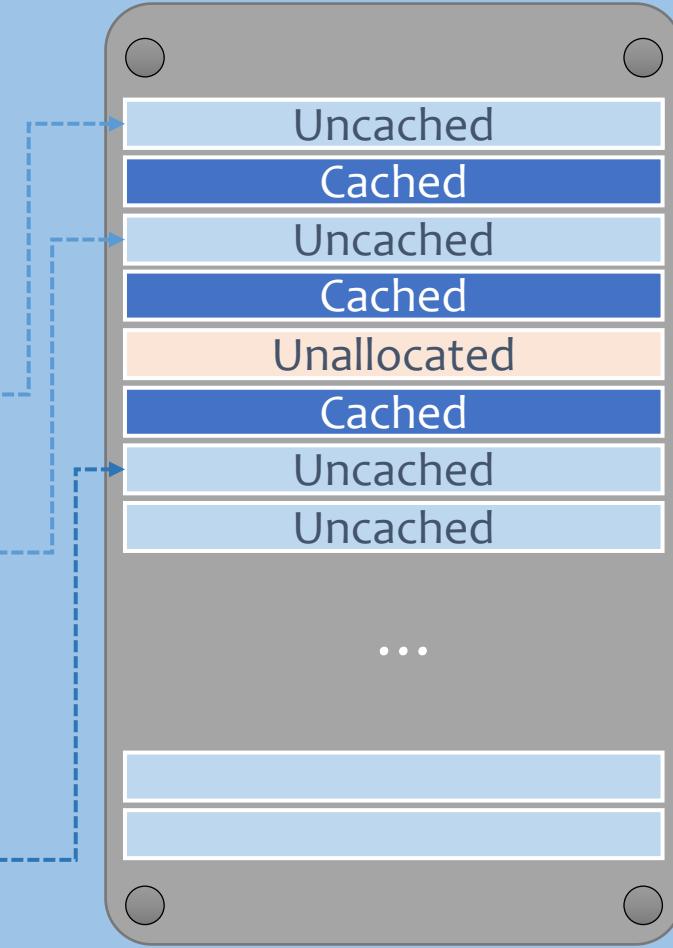
Physical pages

0
1
2
3

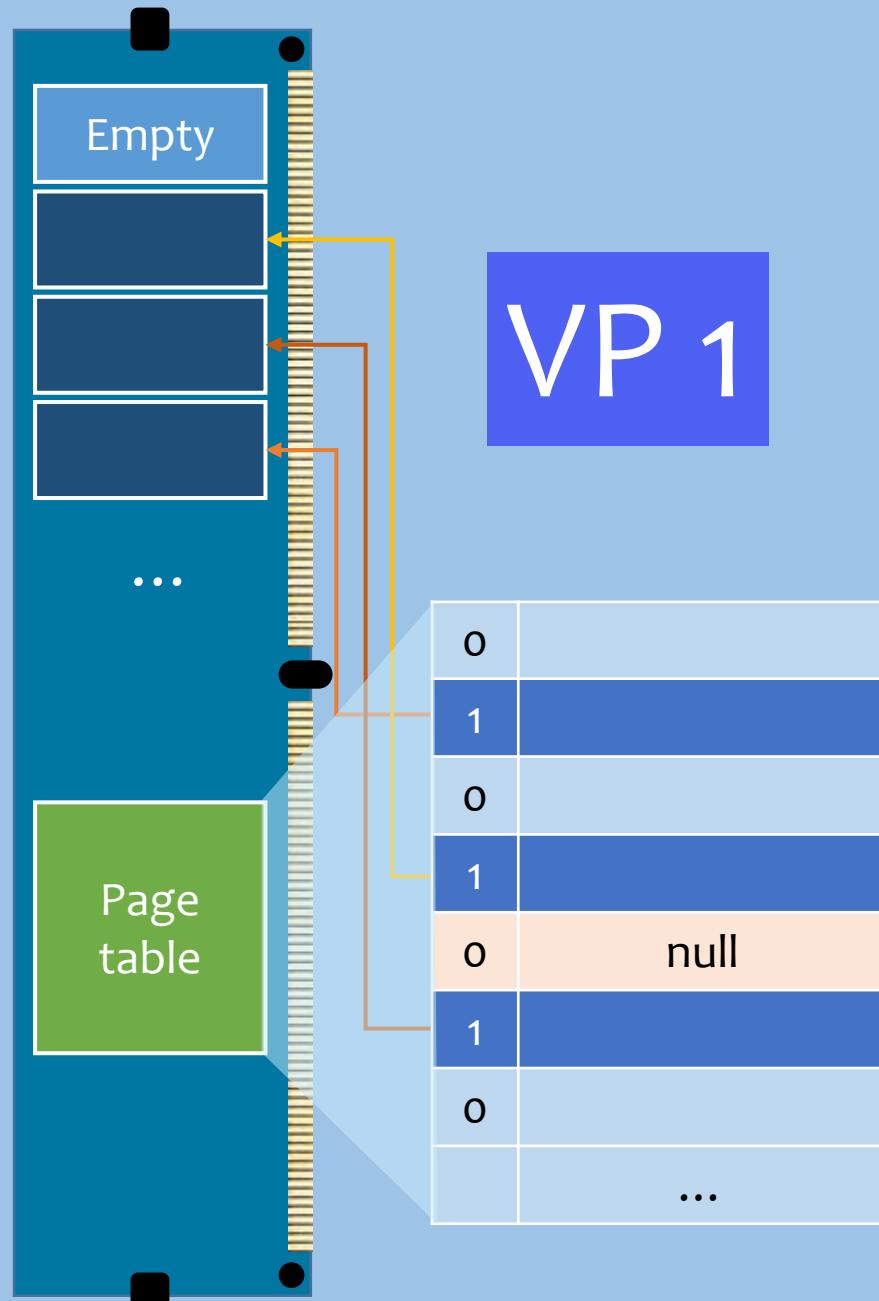


VP 0

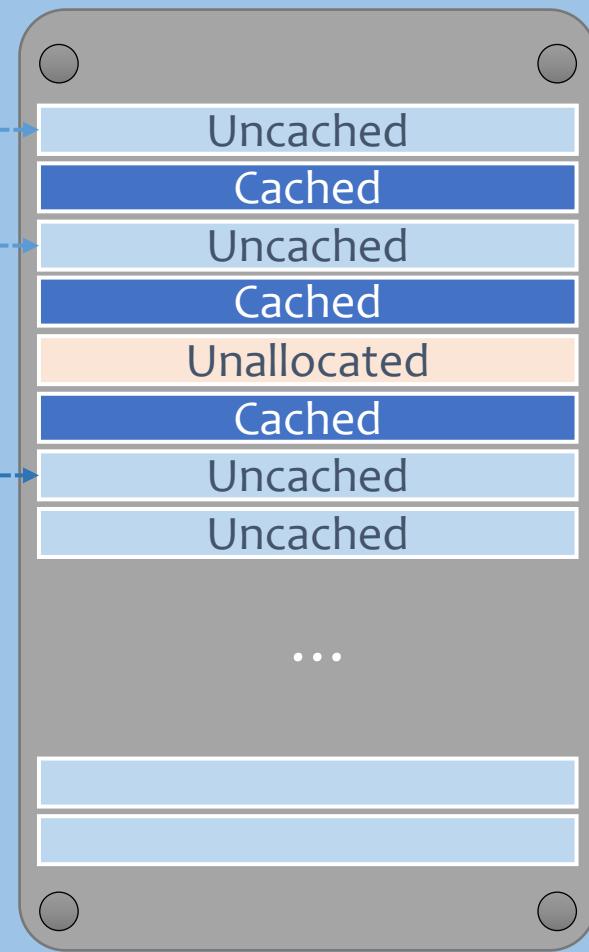
0	null
1	
0	
1	
0	null
1	
0	
	...



Physical pages



Page Hit



Virtual pages

Page Fault

Physical pages

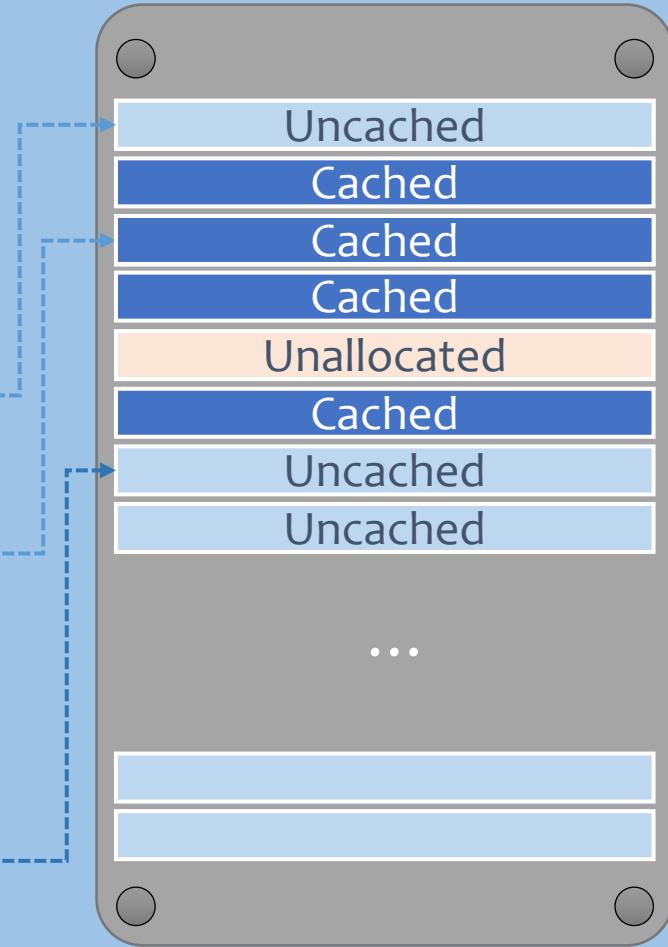
0
1
2
3

Page table



VP 2

0	
1	
1	
1	
0	null
1	
0	
	...



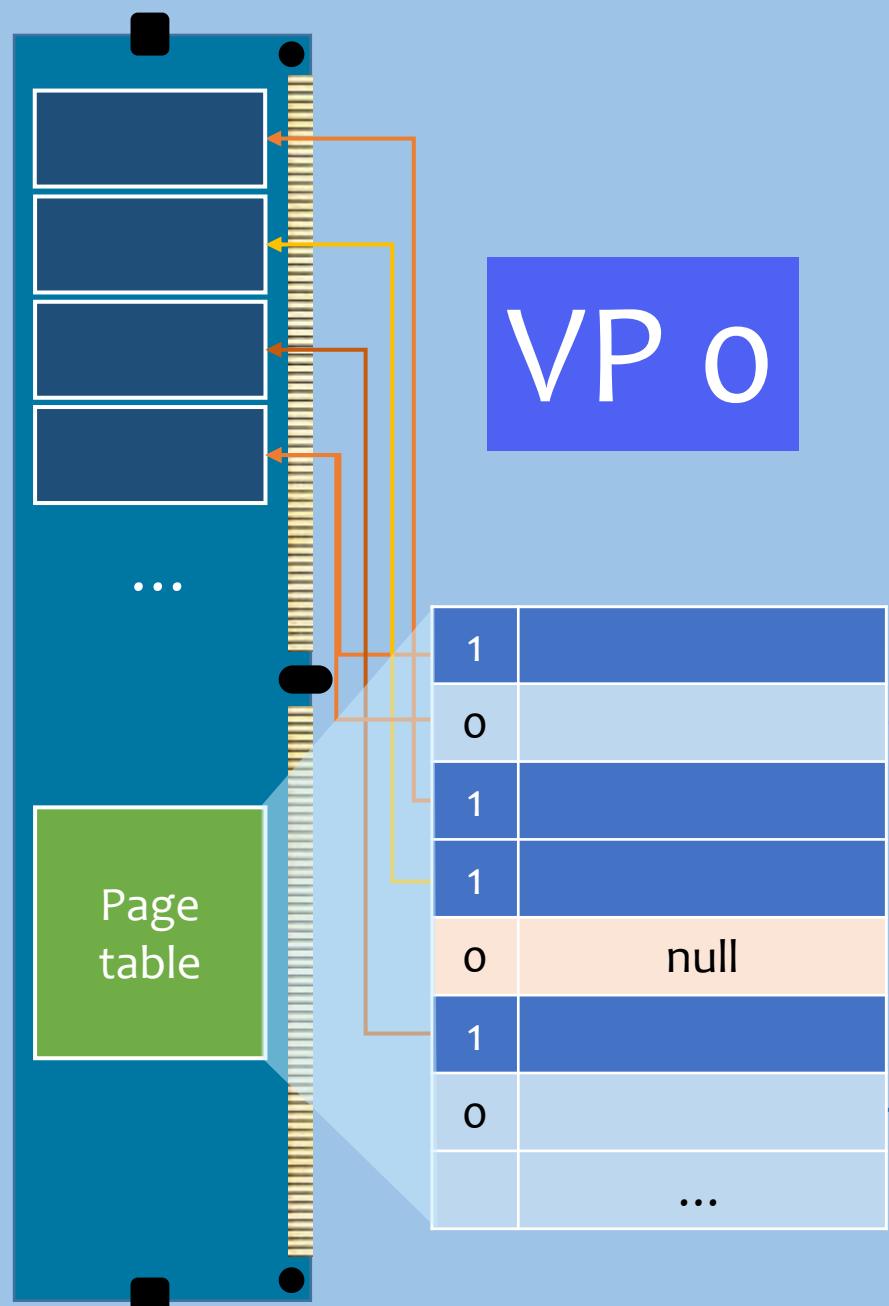
Virtual pages

0
1
2
3

Thrashing

Physical pages

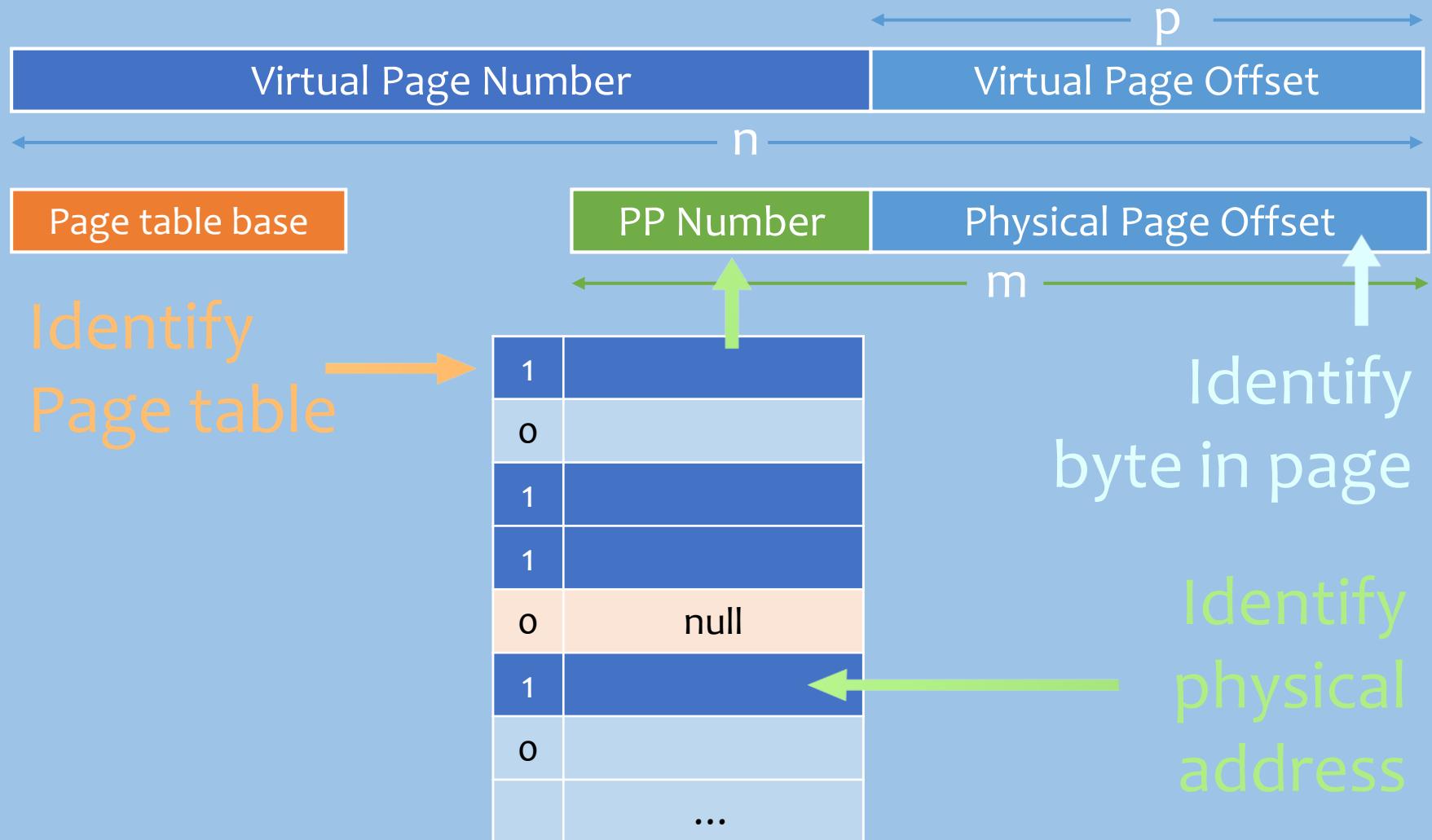
0
1
2
3



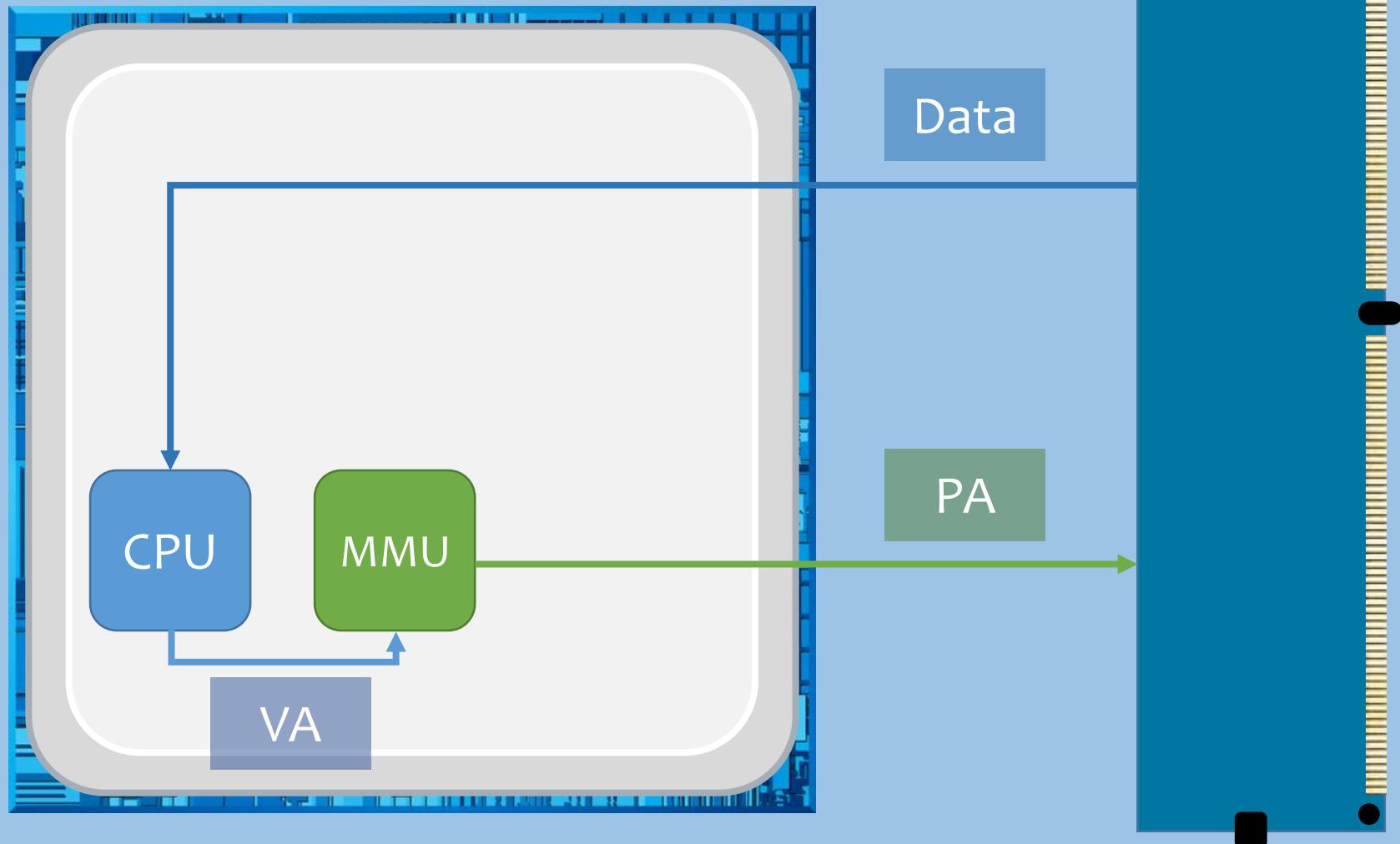
Virtual pages

0
1
2
3

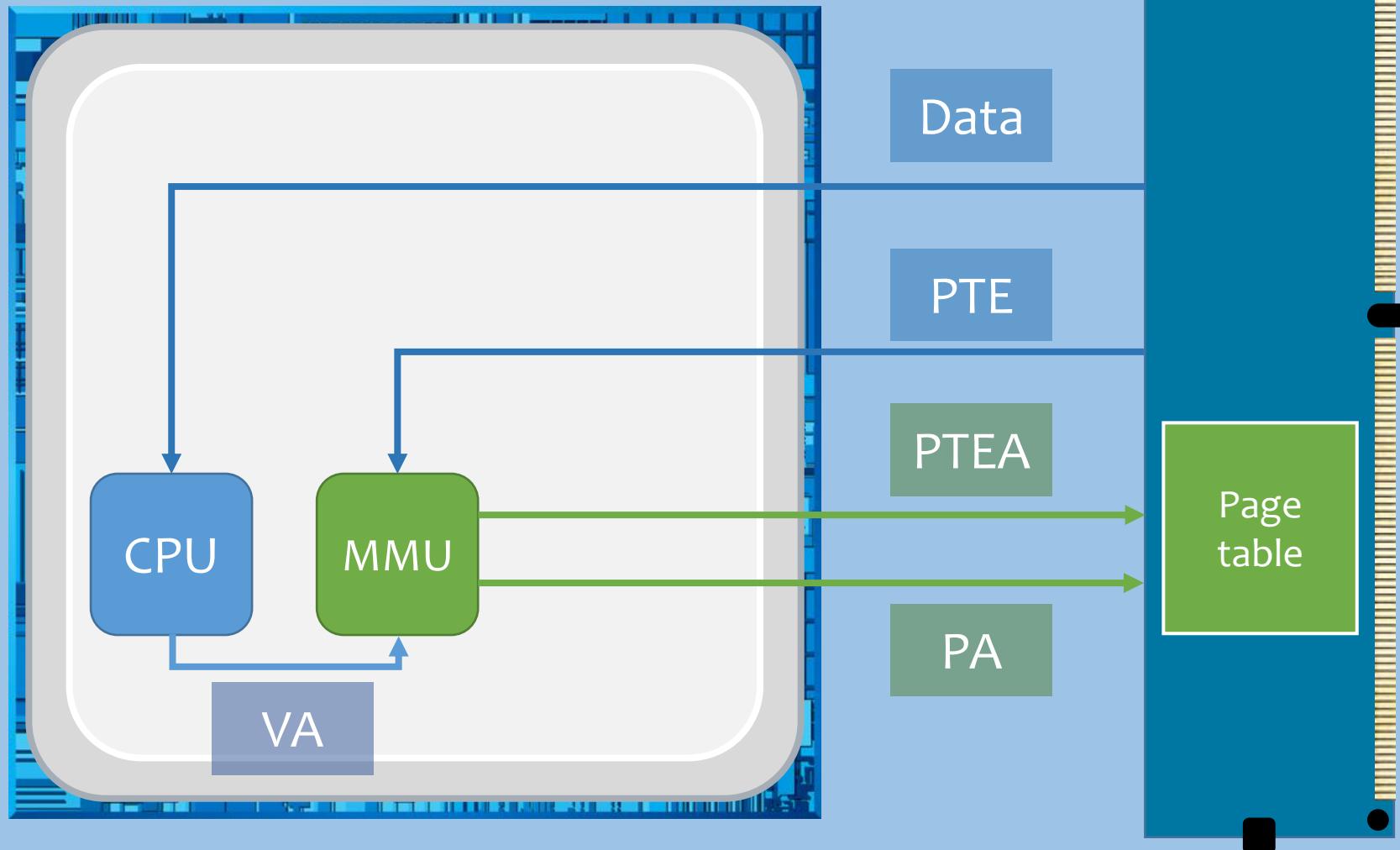
Address Translation



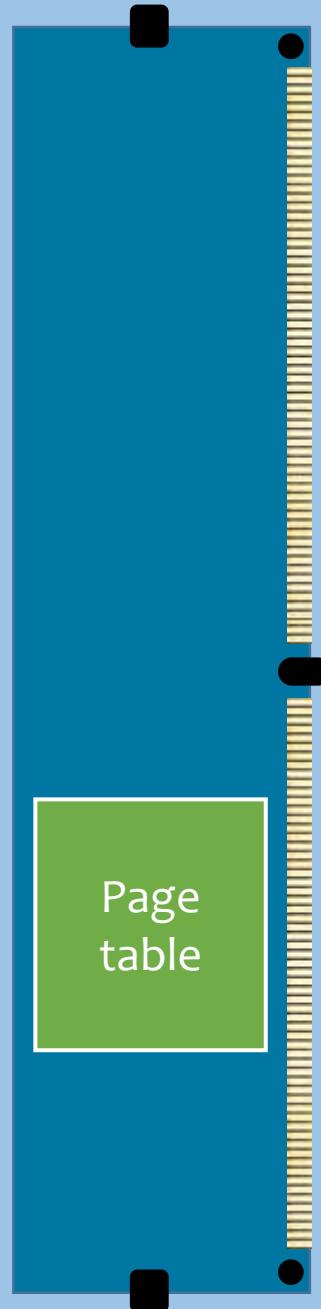
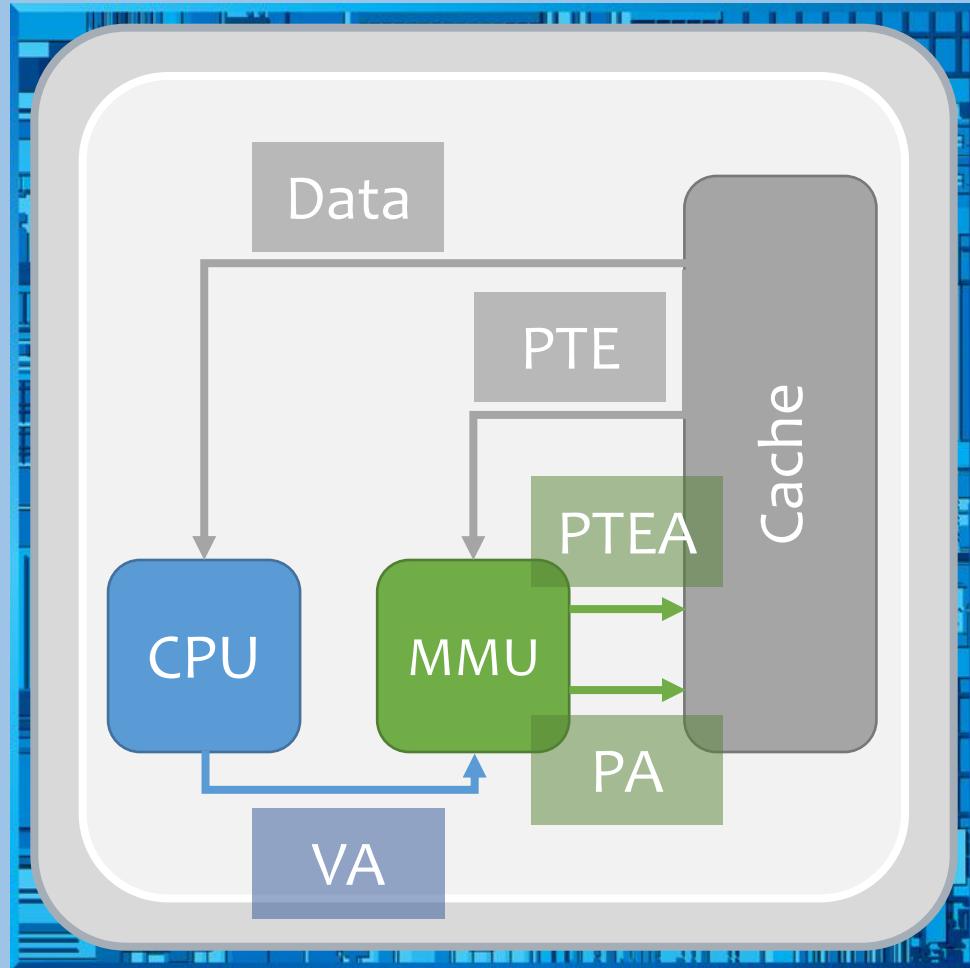
Page Hit



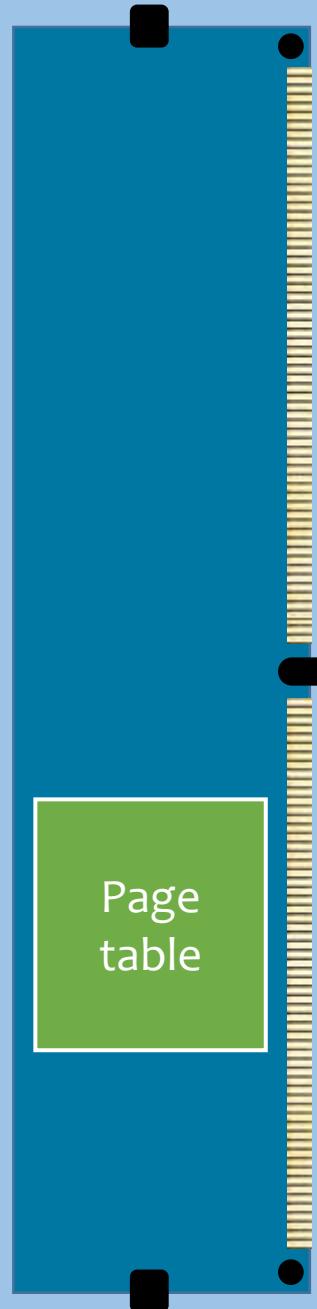
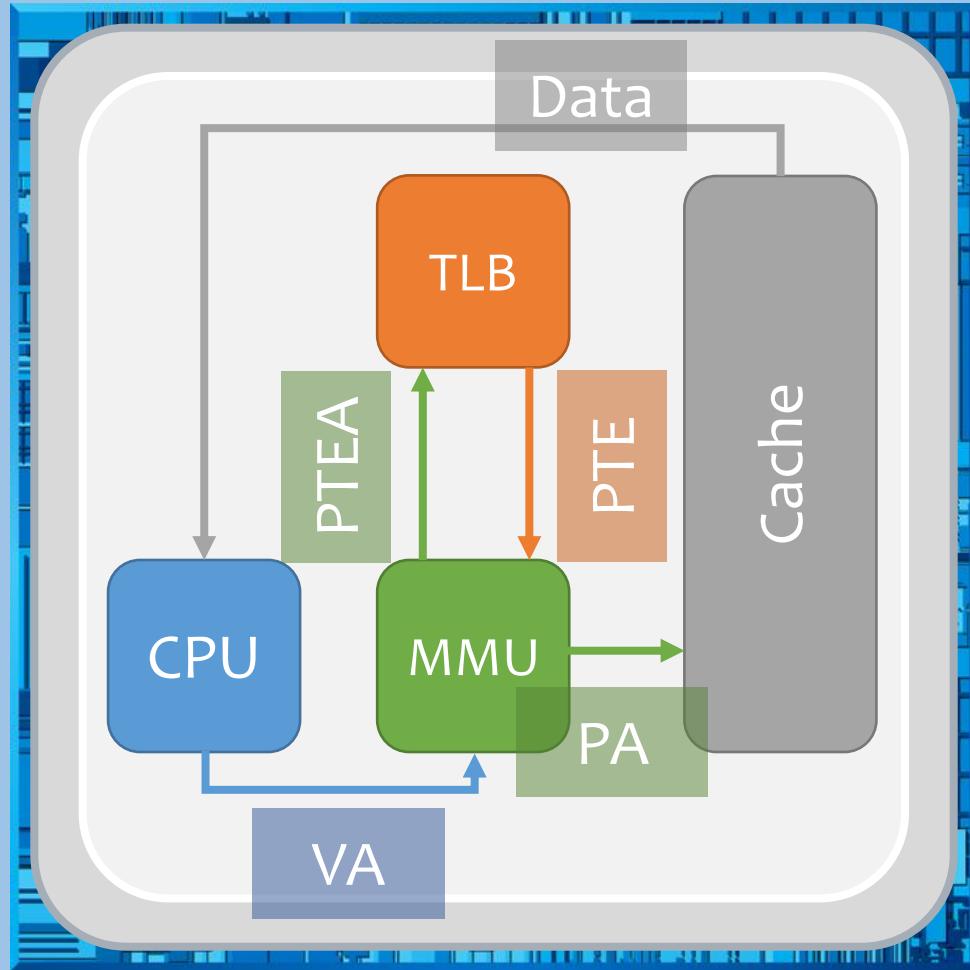
Page Hit



Page Hit



Page Hit



Translation Lookaside Buffer



Summary

- Address
 - Physical
 - Virtual
- Page Hit / Page Fault
- Translation Lookaside Buffer