15-213 Recitation 9

Introduction to Computer Systems

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31 October, 2013

Today

- Shell Lab Questions
- Virtual Memory

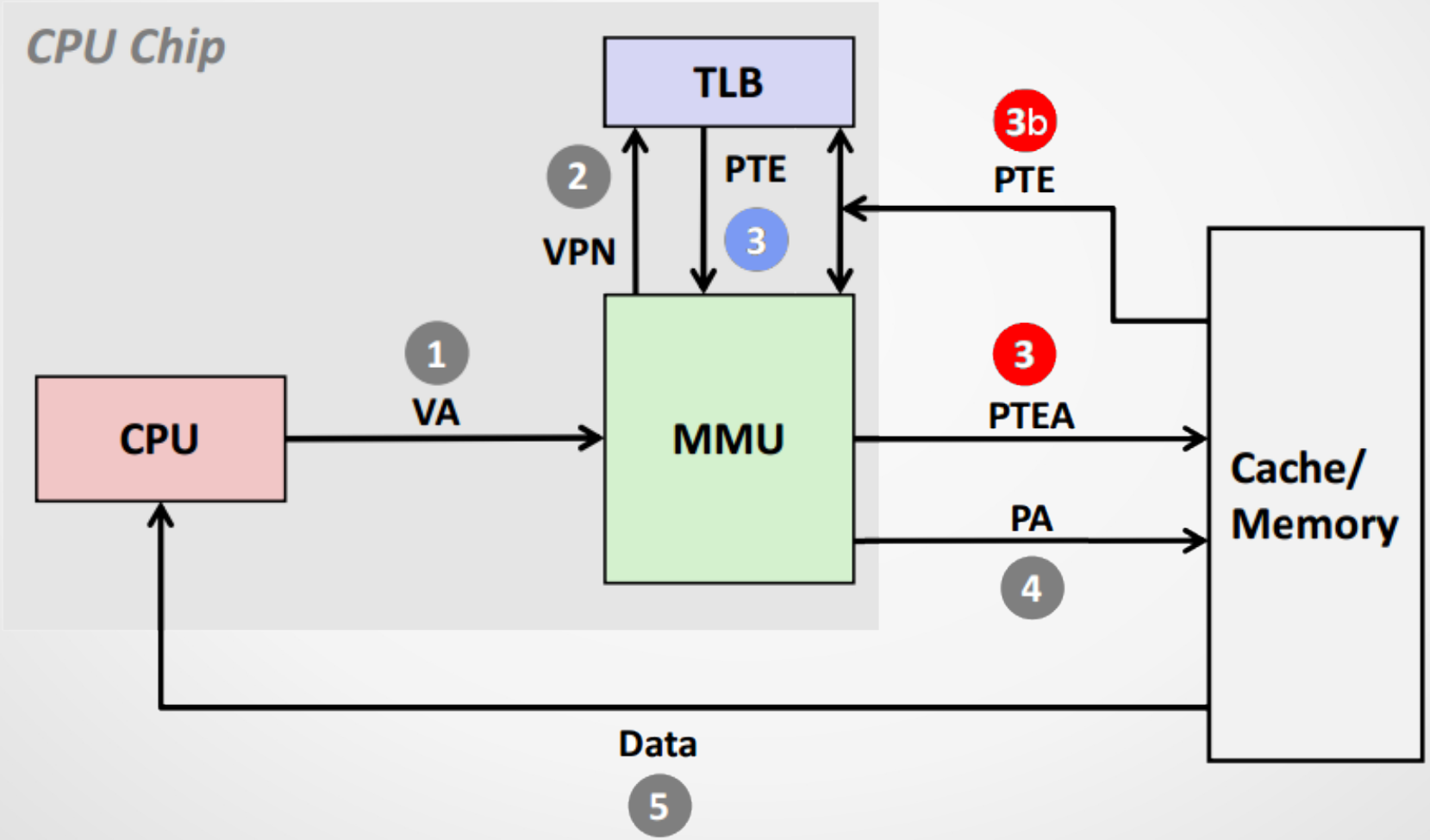
Shell Lab

- Due 4th November, this Monday
- Any Questions?

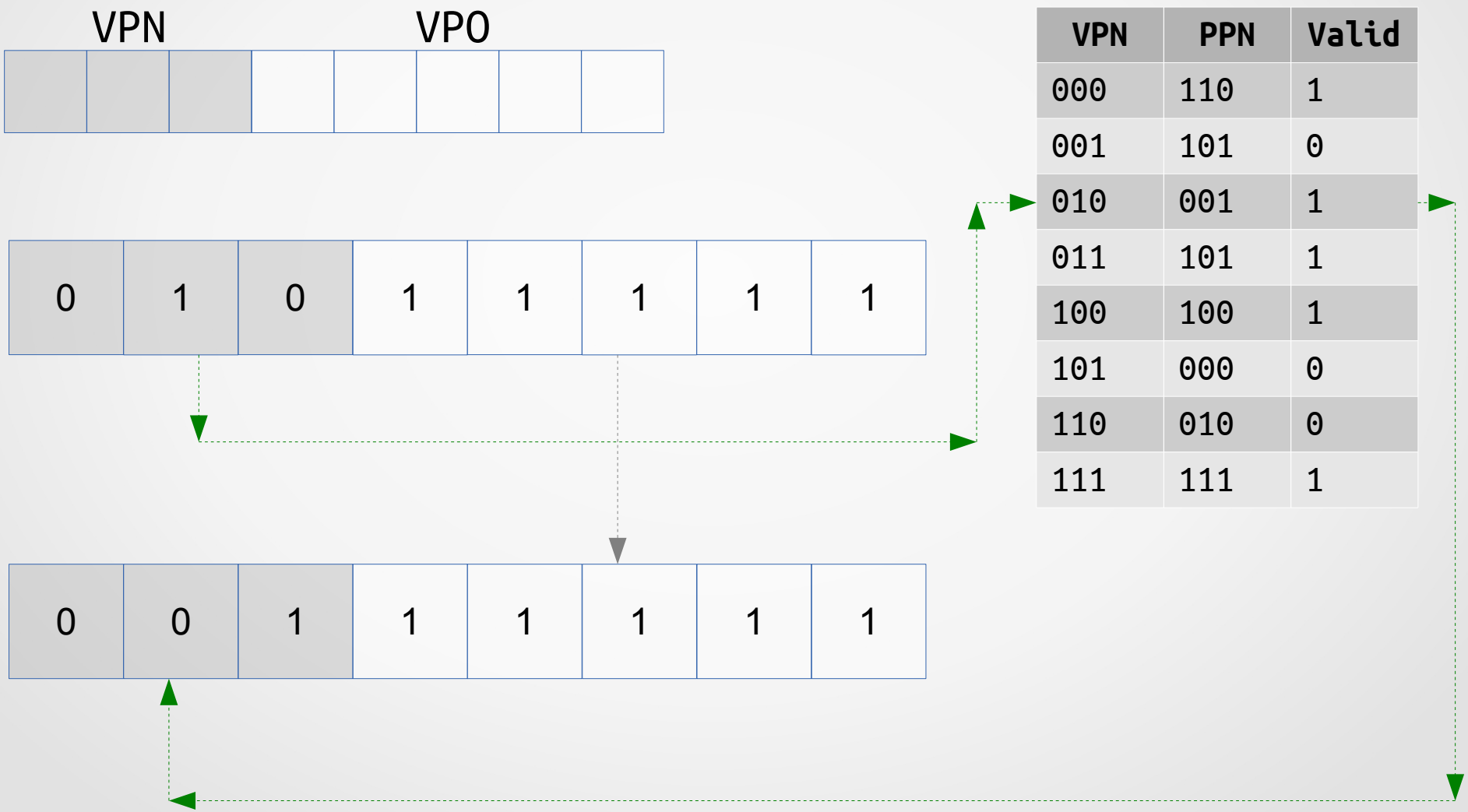
Virtual Memory

- Really cool concept
  - Every process thinks it has the complete RAM to itself
  - Processes can even be made to believe that they have more RAM than the actual physical memory

An Overview

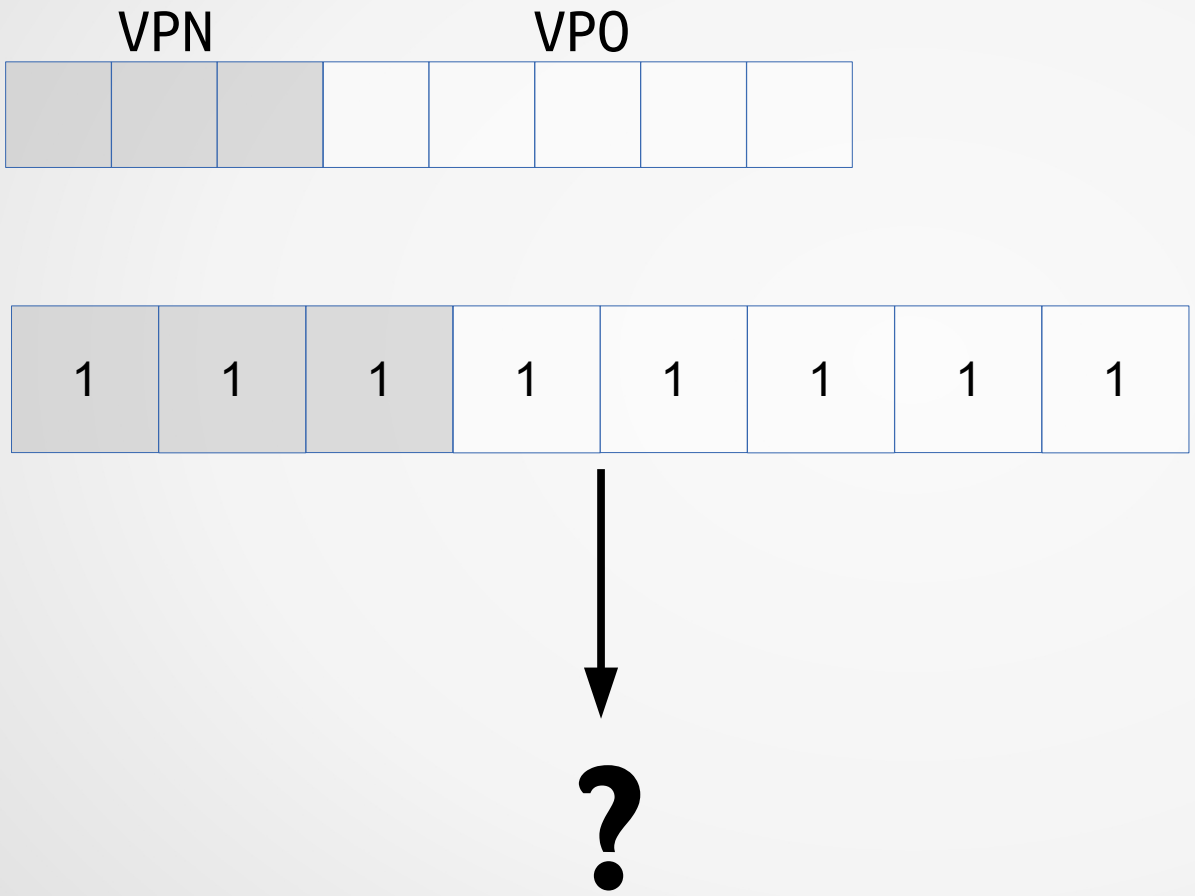

CPU Chip
TLB
2
VPN
PTE
3
3b
PTE
1
VA
CPU
MMU
3
PTEA
PA
4
Cache/
Memory
Data
5

Lets do an example!



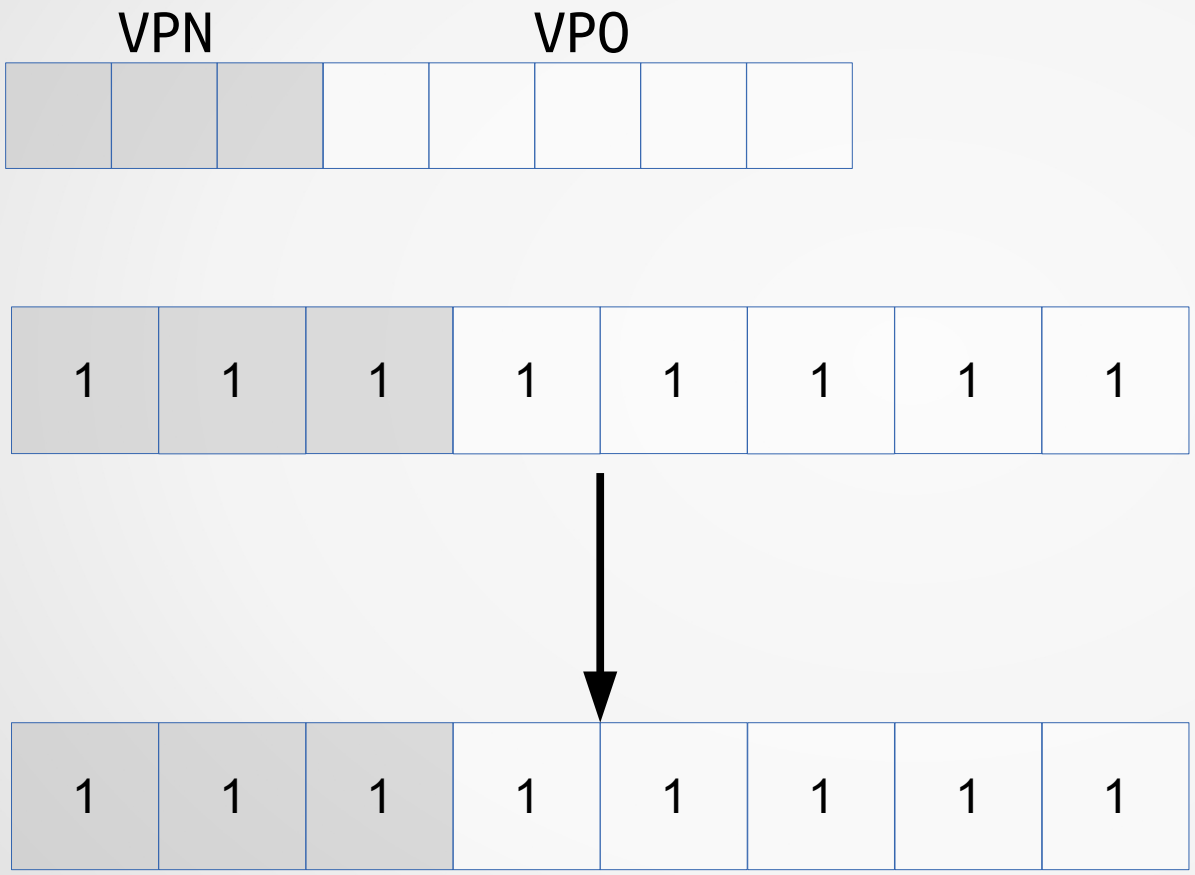
VPN	PPN	Valid
000	110	1
001	101	0
010	001	1
011	101	1
100	100	1
101	000	0
110	010	0
111	111	1

Lets do an example!



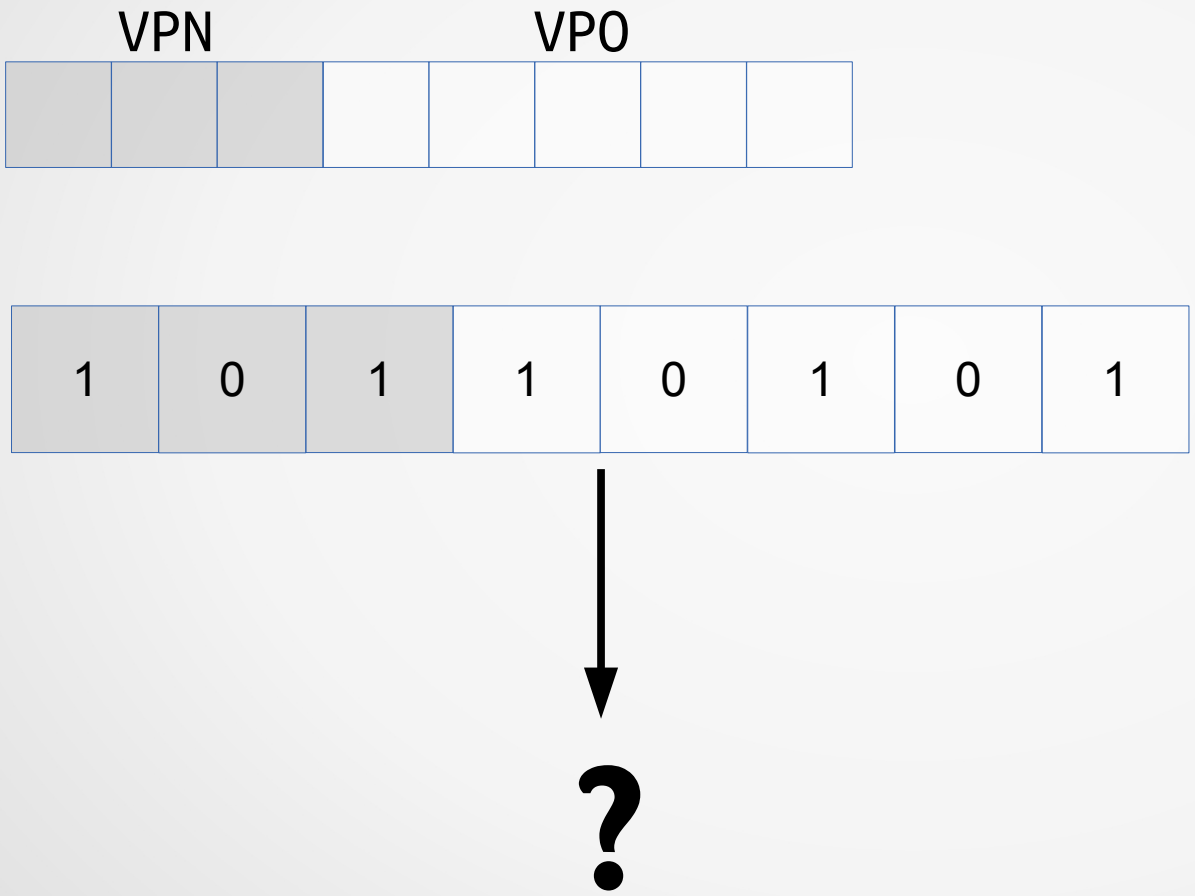
VPN	PPN	Valid
000	110	1
001	101	0
010	001	1
011	101	1
100	100	1
101	000	0
110	010	0
111	111	1

Lets do an example!



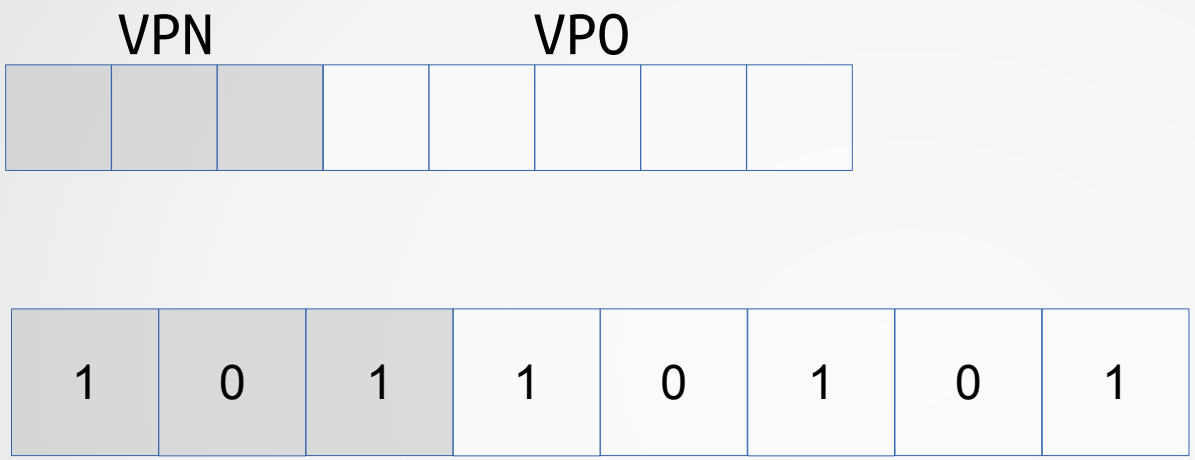
VPN	PPN	Valid
000	110	1
001	101	0
010	001	1
011	101	1
100	100	1
101	000	0
110	010	0
111	111	1

Lets do an example!



VPN	PPN	Valid
000	110	1
001	101	0
010	001	1
011	101	1
100	100	1
101	000	0
110	010	0
111	111	1

Lets do an example!

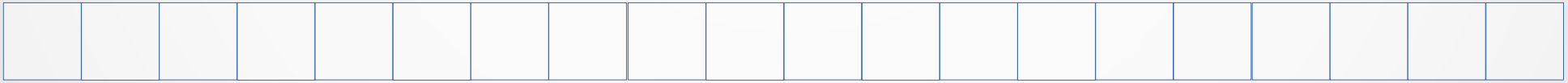


VPN	PPN	Valid
000	110	1
001	101	0
010	001	1
011	101	1
100	100	1
101	000	0
110	010	0
111	111	1

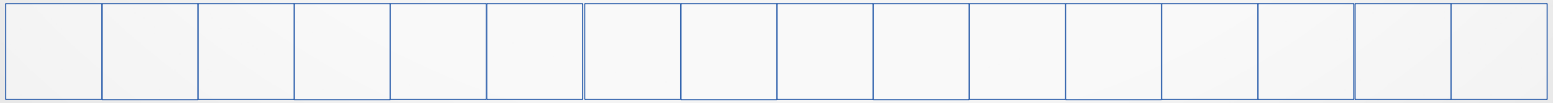
Page fault!

Lets do something more complicated!

- Virtual addresses are 20 bits wide
- Physical addresses are 16 bits wide
- The page size is 4096 bytes
- The TLB is 4-way set associative with 16 total entries



Virtual Address



Physical Address

Lets decode!

- 0x7E37C

Parameter	Value
VPN	0x
TLB Index	0x
TLB Tag	0x
TLB Hit?	
Page Fault	
PPN	0x

TLB			
Index	Tag	PPN	Valid
0	03	B	1
	07	6	0
	28	3	1
	01	F	0
1	31	0	1
	12	3	0
	07	E	1
	0B	1	1
2	2A	A	0
	11	1	0
	1F	8	1
	07	5	1
3	07	3	1
	3F	F	0
	10	D	0
	32	0	0

Page Table					
VPN	PPN	Valid	VPN	PPN	Valid
00	7	1	10	6	0
01	8	1	11	7	0
02	9	1	12	8	0
03	A	1	13	3	0
04	6	0	14	D	0
05	3	0	15	B	0
06	1	0	16	9	0
07	8	0	17	6	0
08	2	0	18	C	1
09	3	0	19	4	1
0A	1	1	1A	F	0
0B	6	1	1B	2	1
0C	A	1	1C	0	0
0D	D	0	1D	E	1
0E	E	0	1E	5	1
0F	D	1	1F	3	1

Lets decode!

- 0x7E37C

0	1	1	1	1	1	1	0	0	0	1	1	0	1	1	1	1	1	0	0

Parameter	Value
VPN	0x7E
TLB Index	0x2
TLB Tag	0x1F
TLB Hit?	yes
Page Fault	no
PPN	0x8

TLB			
Index	Tag	PPN	Valid
0	03	B	1
	07	6	0
	28	3	1
	01	F	0
1	31	0	1
	12	3	0
	07	E	1
	0B	1	1
2	2A	A	0
	11	1	0
	1F	8	1
	07	5	1
3	07	3	1
	3F	F	0
	10	D	0
	32	0	0

Page Table					
VPN	PPN	Valid	VPN	PPN	Valid
00	7	1	10	6	0
01	8	1	11	7	0
02	9	1	12	8	0
03	A	1	13	3	0
04	6	0	14	D	0
05	3	0	15	B	0
06	1	0	16	9	0
07	8	0	17	6	0
08	2	0	18	C	1
09	3	0	19	4	1
0A	1	1	1A	F	0
0B	6	1	1B	2	1
0C	A	1	1C	0	0
0D	D	0	1D	E	1
0E	E	0	1E	5	1
0F	D	1	1F	3	1

1	0	0	0	0	0	1	1	0	1	1	1	1	1	0	0

Lets decode!

- 0x16a48

Parameter	Value
VPN	0x
TLB Index	0x
TLB Tag	0x
TLB Hit?	
Page Fault	
PPN	0x

TLB			
Index	Tag	PPN	Valid
0	03	B	1
	07	6	0
	28	3	1
	01	F	0
1	31	0	1
	12	3	0
	07	E	1
	0B	1	1
2	2A	A	0
	11	1	0
	1F	8	1
	07	5	1
3	07	3	1
	3F	F	0
	10	D	0
	32	0	0

Page Table					
VPN	PPN	Valid	VPN	PPN	Valid
00	7	1	10	6	0
01	8	1	11	7	0
02	9	1	12	8	0
03	A	1	13	3	0
04	6	0	14	D	0
05	3	0	15	B	0
06	1	0	16	9	0
07	8	0	17	6	0
08	2	0	18	C	1
09	3	0	19	4	1
0A	1	1	1A	F	0
0B	6	1	1B	2	1
0C	A	1	1C	0	0
0D	D	0	1D	E	1
0E	E	0	1E	5	1
0F	D	1	1F	3	1

Lets decode!

- 0x16a48

0	0	0	1	0	1	1	0	1	0	1	0	0	1	0	0	1	0	0	0

Parameter	Value
VPN	0x16
TLB Index	0x2
TLB Tag	0x5
TLB Hit?	no
Page Fault	yes
PPN	0x-

TLB			
Index	Tag	PPN	Valid
0	03	B	1
	07	6	0
	28	3	1
	01	F	0
1	31	0	1
	12	3	0
	07	E	1
	0B	1	1
2	2A	A	0
	11	1	0
	1F	8	1
	07	5	1
3	07	3	1
	3F	F	0
	10	D	0
	32	0	0

Page Table					
VPN	PPN	Valid	VPN	PPN	Valid
00	7	1	10	6	0
01	8	1	11	7	0
02	9	1	12	8	0
03	A	1	13	3	0
04	6	0	14	D	0
05	3	0	15	B	0
06	1	0	16	9	0
07	8	0	17	6	0
08	2	0	18	C	1
09	3	0	19	4	1
0A	1	1	1A	F	0
0B	6	1	1B	2	1
0C	A	1	1C	0	0
0D	D	0	1D	E	1
0E	E	0	1E	5	1
0F	D	1	1F	3	1

Lets decode!

- 0x18ab7

Parameter	Value
VPN	0x
TLB Index	0x
TLB Tag	0x
TLB Hit?	
Page Fault	
PPN	0x

TLB			
Index	Tag	PPN	Valid
0	03	B	1
	07	6	0
	28	3	1
	01	F	0
1	31	0	1
	12	3	0
	07	E	1
	0B	1	1
2	2A	A	0
	11	1	0
	1F	8	1
	07	5	1
3	07	3	1
	3F	F	0
	10	D	0
	32	0	0

Page Table					
VPN	PPN	Valid	VPN	PPN	Valid
00	7	1	10	6	0
01	8	1	11	7	0
02	9	1	12	8	0
03	A	1	13	3	0
04	6	0	14	D	0
05	3	0	15	B	0
06	1	0	16	9	0
07	8	0	17	6	0
08	2	0	18	C	1
09	3	0	19	4	1
0A	1	1	1A	F	0
0B	6	1	1B	2	1
0C	A	1	1C	0	0
0D	D	0	1D	E	1
0E	E	0	1E	5	1
0F	D	1	1F	3	1

Lets decode!

- 0x18ab7

0	0	0	1	1	0	0	0	1	0	1	0	1	0	1	1	0	1	1	1

Parameter	Value
VPN	0x18
TLB Index	0x0
TLB Tag	0x6
TLB Hit?	no
Page Fault	yes
PPN	0xC

TLB			
Index	Tag	PPN	Valid
0	03	B	1
	07	6	0
	28	3	1
	01	F	0
1	31	0	1
	12	3	0
	07	E	1
	0B	1	1
2	2A	A	0
	11	1	0
	1F	8	1
	07	5	1
3	07	3	1
	3F	F	0
	10	D	0
	32	0	0

Page Table					
VPN	PPN	Valid	VPN	PPN	Valid
00	7	1	10	6	0
01	8	1	11	7	0
02	9	1	12	8	0
03	A	1	13	3	0
04	6	0	14	D	0
05	3	0	15	B	0
06	1	0	16	9	0
07	8	0	17	6	0
08	2	0	18	C	1
09	3	0	19	4	1
0A	1	1	1A	F	0
0B	6	1	1B	2	1
0C	A	1	1C	0	0
0D	D	0	1D	E	1
0E	E	0	1E	5	1
0F	D	1	1F	3	1

1	1	0	0	1	0	1	0	1	0	1	1	0	1	1	1

Any Questions?