

## Virtual Memory

- Protection via virtual memory
  - Keeps processes in their own memory space
- Role of architecture:
  - Provide user mode and supervisor mode
  - Protect certain aspects of CPU state
  - Provide mechanisms for switching between user mode and supervisor mode
  - Provide mechanisms to limit memory accesses
  - Provide TLB to translate addresses

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## Virtual Memory

- Virtual memory references are generated by the compiler
- Physical memory is shared between many processes.
- Physical memory may be smaller than virtual memory.
- Need some mechanism to translate between virtual and physical memory.
- Need also a protection scheme to allow processes to reference only memory that belongs to them.

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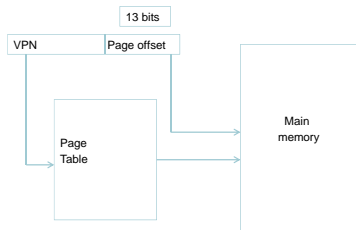
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## Virtual Memory

- Page table is used to translate virtual memory to physical memory



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## TLB

- Every memory reference takes 2 memory accesses.
- TLB is used to improve performance
- TLB is a small cache to store part of the page table

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## Page Table Contents

- The memory location for the page OR DISK
- Valid bits
- Protection bits (who can access it)

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## Virtual address and Caches

- Should the cache have physical addresses or virtual addresses.
- Does it make any difference?

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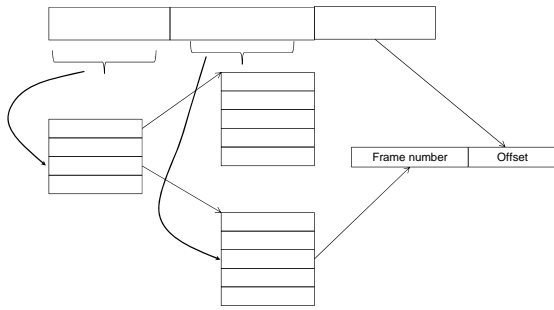
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## Hierarchical Page Tables



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