Practical Memory Management

Jonathan Windle

University of East Anglia

J.Windle@uea.ac.uk

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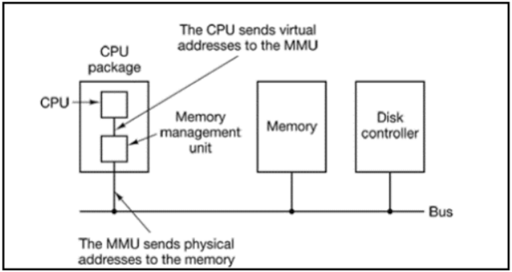
Memory Management Unit (MMU)

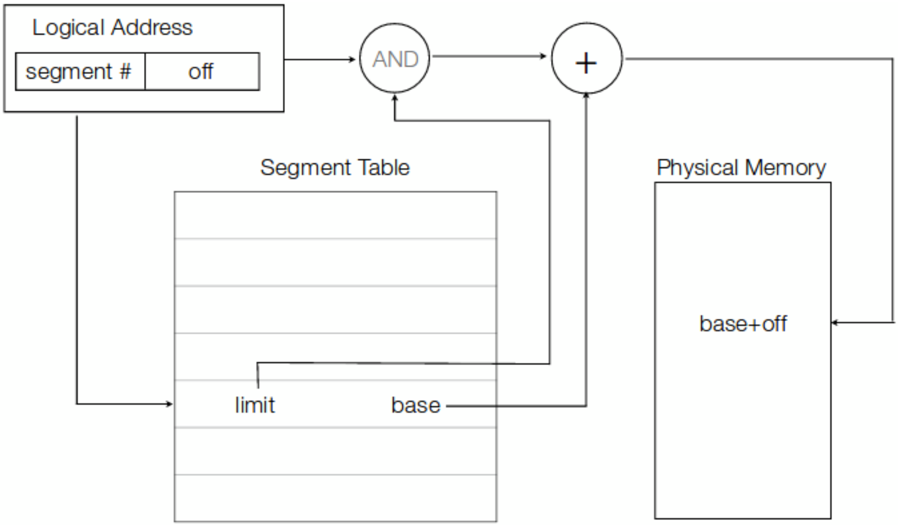
- MMU is hardware that provides the translation from a virtual address to a physical address
- Works in conjunction with OS memory manager that allocates/deallocates memory
- MMU sits between CPU and system bus
- MMU allows implementation of virtual/logical addresses
- Location:



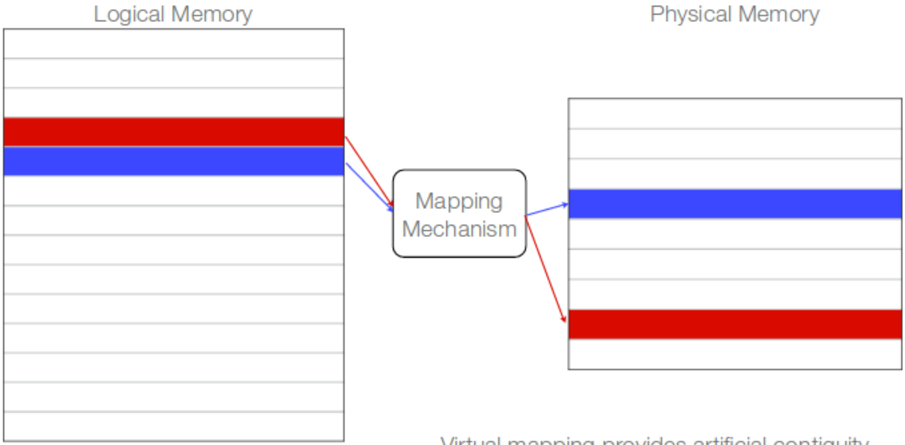
Provides

- Non-Contiguous memory segmentation by maintaining segment table for each process
- A segment index and address of each segment
- Segment table is really just an array:
    - Segment number is index into array
    - Contents are base and limit values

Segment/page table



Mapping



Virtual mapping provides artificial contiguity.

Paging

- Need to efficiently map between address spaces
- Cannot map individual locations, would take more memory than is physically available
- Instead system tracks blocks of memory
- Virtual memory is divided into pages
- Physical memory is divided into page frames
- Typical page sizes range from 512Bytes to 16KB.
- Each process has a page table:
  - An array of page table entries
  - One entry for each page in memory
- A page table entry is typically a 32-bit word
- Allows memory to be protected
- Process can address only pages in page table
- Switching processes means switching onlypage table address in MMU.

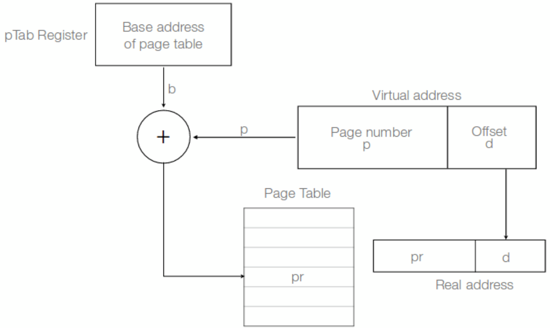
Page Table Entries

- Elements in the page table entry:
  - **pFNo:** Page frame number
  - **pAccess:** Protection information
  - **pAvail:** Present/Absent flag
  - **pUsed:** Referenced flag
  - **pDirty:** Modified flag
- For each memory reference, the bits of a page are tested to ensure access is valid
- All tests are done in parallel in hardware

Cache	pAccess	pAvail	pUsed	pDirty	pFNo
0	R/W	T	T	F	0x0012

MMU registers for Paged Virtual Memory

- MMU must be able to locate pages in memory
- For this it uses:
  - **pTab:** Page table (real) addressfor current process
  - **pTabSize:** Number of pages in virtual address space
- Demand Paged Virtual Memory:



Page Faults I

- pAvail signifies if a page is available in main memory
  - CPU cannot access secondary memory directly
  - How does it read from page?
- MMU generates a page fault
- CPU is interrupted and required page is swapped in.
- Control is transferred to schedular via a trap
- Faulted process is blocked
- Control transferred to memory manager
- DMA used to transfer requested page
- Memory manager selects a frame to store the page.
- If no page frames are empty, one must be replaced
- Possiblepage replacement strategies
  - Least frequently used
  - Least recently used

Page Faults II

- First-in, First-out

- Least frequently used is most favoured
- MEmory manager checks pDirty bit for old page, if set:
  - Initiate disc transferto save the page
  - Initiate disc transfer to fetch new page
  - Move faulted process to ready queue

Working Sets

- The working set is the active pages over a period of time
  - Usually much less than entire virtual address space
  - Page numbers change gradually over time
- Memory manager imposes a fixed working set size:
  - size is important, to avoid thrashing
  - Excessive disc activity introduces bottlenecks
- Can schedule process only if all working set is available

Working Sets Example

- Suppose:
  - A process has 8 virtual pages
  - Memory manager allocates a working set of 4
  - Page frames in working set are initally empty
  - Memory manager uses least-frequently-used policy
- Assume following sequence of page references:
  - 0,2,4,6,2,1,4,3,2,7,5,3,2,7,6,3,7,2

Fault Count	LRU	Pages loaded after request.				Seq before next fault.
1	-	0	-	-	-	0
2	-	0	2	-	-	2
3	-	0	2	4	-	4
4	-	0	2	4	6	6 2
5	0	1	2	4	6	1 4
6	6	1	2	4	3	3 2
7	1	7	2	4	3	7
8	4	7	2	5	3	5 3 2 7
9	5	7	2	6	3	6 3 7 2

0 2 4 6 2 1 4 3 2 7 5 3 2 7 6 3 7 2

Paging and Segmentation

- Fixed block sizes are referred to as pages
- Variable block sizes are referred to as segments
  - Concept of virtual address being formed of a segment ID and an offset is similar
- Possible to combine both paging and segmentation
- Also possible to have multi-level page tables

Summary

- Programs need to be bound to memory:
  - Some instruction arent complete without address
  - Three situations: compile time, load time, run time
- Memory must be protected and shared
  - MMU enables this
  - Process operates in logical address space
  - MMU translates logical address to physical address.

The End