# 605.611 - Foundations of Computer Architecture

# Assignment 09 - Paging

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1. Calculate the size of memory if its address consists of 22 bits and the memory is 2-byte addressable.

   **Answer:** 22 bits = $2^{22}$ locations possible. Since one location is 2 bytes:

   $$\begin{aligned} &= 2^{22} \cdot 2 \text{ bytes} \\ &= 2^{23} \text{ bytes} \\ &= 8 \text{ MB} \end{aligned}$$

2. Calculate the number of bits required in the address for memory having size of 16 GB. Assume the memory is 4-byte addressable.

   **Answer:** The memory is $2^n \cdot 4$ bytes, where $n$ is the number of bits required.

   $$\begin{aligned} 2^n \cdot 4 &= 16 \text{ GB} \\ 2^n \cdot 4 &= 16 \text{ GB} \\ 2^n \cdot 2^2 &= 2^{34} \text{ GB} \\ 2^n &= 2^{32} \text{ GB} \end{aligned}$$

   Therefore, $n = 32$ bits.

3. Consider a system with byte-addressable memory, 32 bit logical addresses, 4 kilobyte page size and page table entries of 4 bytes each. The size of the page table in the system in megabytes is _____.

   ☐ (a) 2

■ (b) 4

□ (c) 8

□ (d) 16

**Answer:**

- Number of bits in logical address: 32 bits
- Page size: 4 KB
- Page table entry size: 4 bytes

32 bits = $2^{32}$ locations possible. The number of entries in the page table:

$$= 4 \text{ GB}/4 \text{ KB}$$
$$= 2^{32}/2^{12}$$
$$= 2^{20} \text{ pages}$$

Therefore, the page table size is:

$$= 2^{20} \cdot 4 \text{ bytes}$$
$$= 4 \text{ MB}$$

4. Consider a machine with 64 MB physical memory and a 32 bit virtual address space. If the page size is 4 KB, what is the approximate size of the page table?

□ (a) 16 MB

□ (b) 8 MB

■ (c) 2 MB

□ (d) 24 MB

**Answer:**

- Size of main memory: 64 MB
- Number of bits in virtual address space: 32 bits
- Page size: 4 KB

Number of bits in physical address:

$$= 64 \text{ MB}$$
$$= 2^{26} \text{ bits}$$

Number of frames:

$$= \text{Size of main memory/Frame size}$$
$$= 64 \text{ MB}/4 \text{ KB}$$
$$= 2^{26}/2^{12} \text{ bits}$$
$$= 2^{14} \text{ bits}$$

Number of page offset bits:

$$= 4 \text{ KB}$$
$$= 2^{12} \text{ bits}$$

Number of entries in page table:

$$= \text{Process size/Page size}$$
$$= 2^{32}/2^{12}$$
$$= 2^{20}$$

Page table size:

$$= 2^{20} \cdot 14 \text{ bits}$$

$$\approx 2^{20} \cdot 2 \text{ bytes}$$

$$\approx 2 \text{ MB}$$

5. In a virtual memory system, size of virtual address is 32-bit, size of physical address is 30-bit, page size is 4 Kbyte and size of each page table entry is 32-bit. The main memory is byte addressable. Which one of the following is the maximum number of bits that can be used for storing protection and other information in each page table entry?

☐ (a) 2

☐ (b) 10

☐ (c) 12

■ (d) 14

**Answer:**

- Number of bits in virtual address = 32 bits
- Number of bits in physical address = 30 bits
- Page size = 4 KB
- Page table entry size = 32 bits

Size of main memory:

$$= 2^{30} \text{ bits}$$

$$= 1 \text{ GB}$$

Number of frames:

$$
\begin{aligned}
&= \text{Size of main memory/Frame size} \\
&= 1 \text{ GB}/4 \text{ KB} \\
&= 2^{30}/2^{12} \text{ bits} \\
&= 2^{18} \text{ bits}
\end{aligned}
$$

Number of bits used for storing other information:

$$
\begin{aligned}
&= \text{Page table entry size} - \text{Number of bits in frame number} \\
&= 32 \text{ bits} - 18 \text{ bits} \\
&= 14 \text{ bits}
\end{aligned}
$$