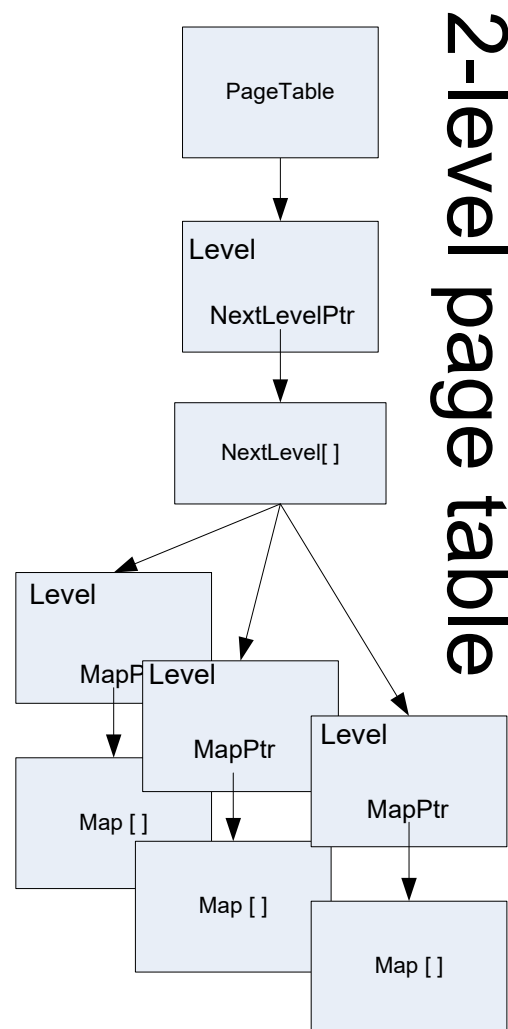


A sample data structure for N-level page tables

Sample Data Structure

- PageTable – Contains information about the tree
- Level – A structure describing a specific level of the page table.
- NextLevel – Array of pointers to the next level.
- Map – Array which maps from a logical page to a physical frame.

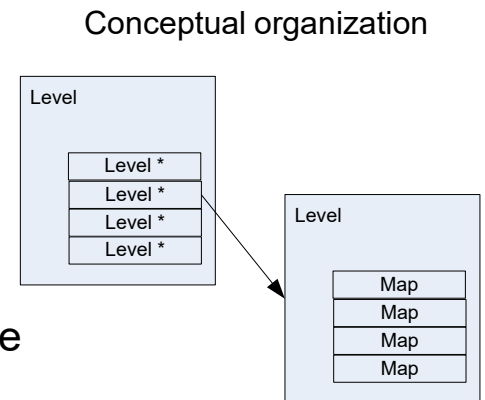


PageTable

- Contains information about the tree:
 - LevelCount: Number of levels
 - BitmaskAry[i]: bit mask for level i
 - ShiftAry[i]: # of bits to shift level i page bits
 - EntryCount[i]: # of possible pages for level i

Levels of the page table

- Each level of the page table is represented by a pair of structures:
 - Interior levels use Level & *NextLevelPtr
 - Leaf levels use Level and *MapPtr
 - Conceptually, Level contains an array of pointers to the next level (Level *) or Map entries
 - C/C++ does not permit variable size structures.
 - We circumnavigate this by using a pointer to a runtime allocated structure.
 - See the course FAQ for allocating arrays at runtime.
- Useful information to have in Level
 - Current depth
 - Pointer to the PageTable structure/object to access information



Initialization

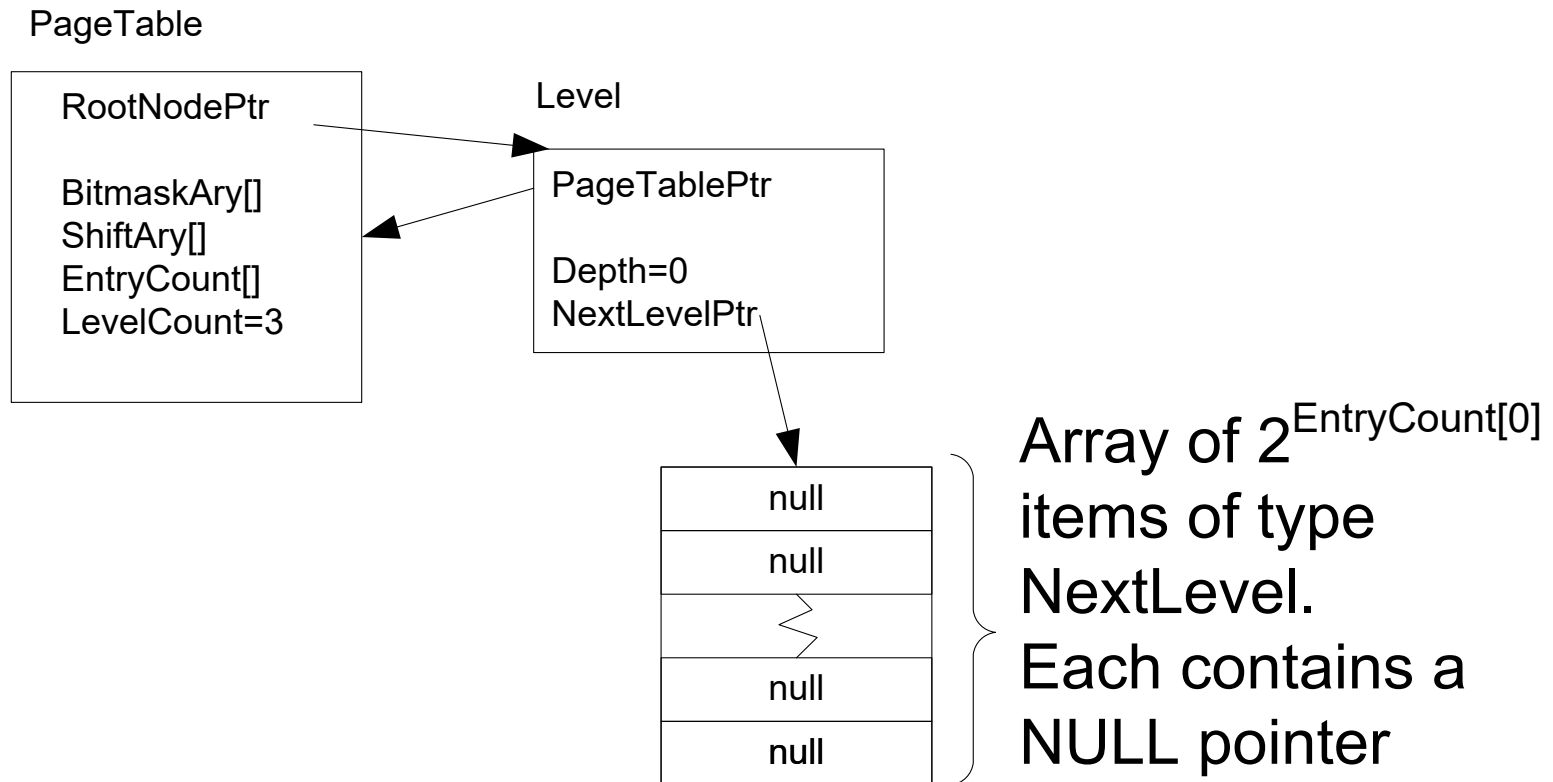
- Suppose we wanted to create a 3 level page table with 8 bits per level on a 32 bit address space.
 - We would allocate a PageTable structure and populate it with the following values:
 - LevelCount = 3
 - BitmaskAry = {0xFF000000, 0x00FF0000, 0x0000FF00}
 - ShiftAry = {24, 16, 8}
 - EntryCount = {2⁸, 2⁸, 2⁸}
- BitmaskAry, ShiftAry, and EntryCount should all be computed dynamically based on your pagetable specification.

Initialize Data Structure

- In addition, we would allocate the level 0 information:
 - Allocate a Level structure
 - Set its depth to 0
 - Have it point back to the PageTable
 - Allocate an array of 256 pointers to Level structures.
 - Initialize all to NULL (no level 1 entries)
 - If this had been a 1 level page table we would have allocated map structures instead of pointers to Levels

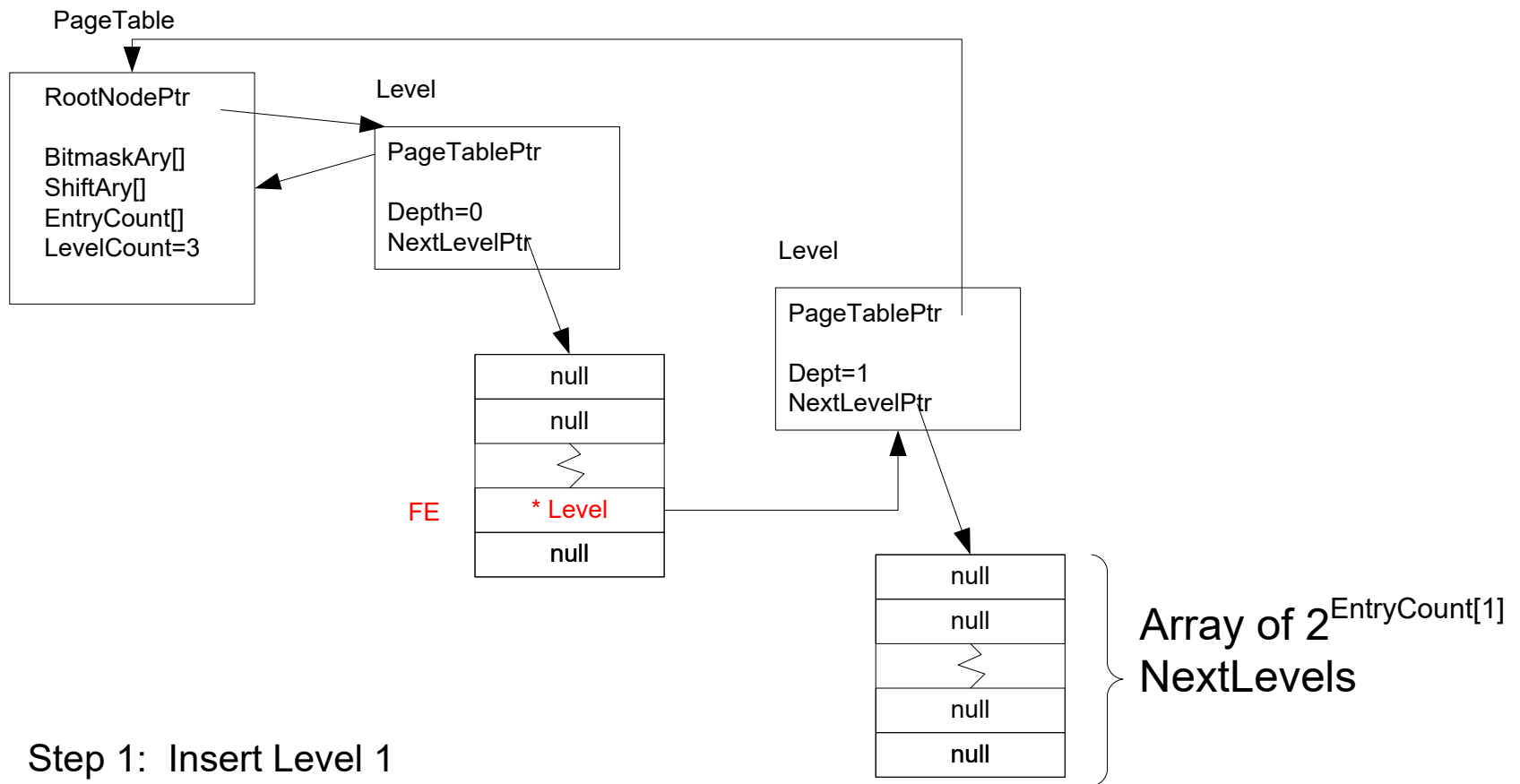
3 level example

- Empty table



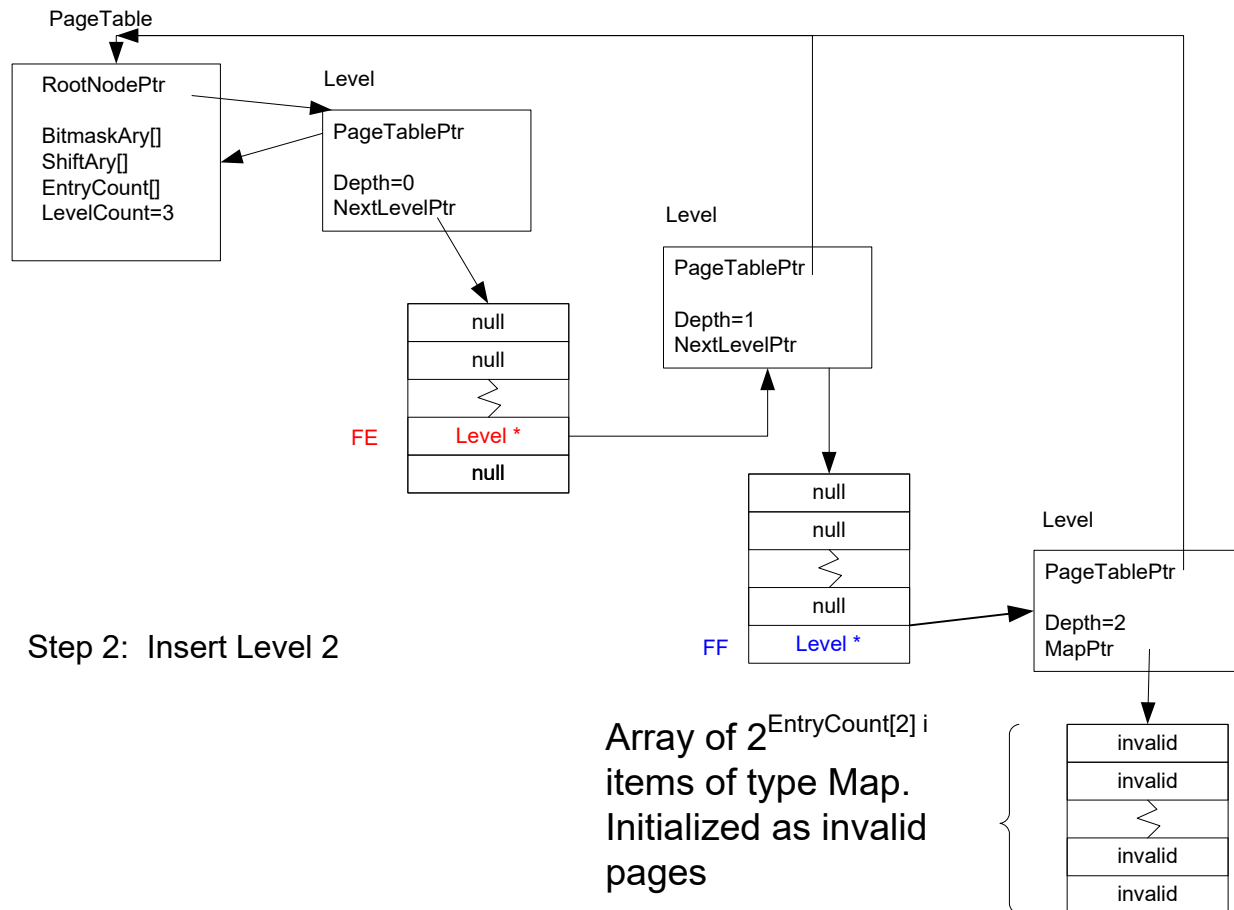
Page Insertion

Assume 32 bit word, 8 bit pages for each level
Insert address 0x**FE****FF****FE**C2 mapping to frame 3



Page Insertion

Assume 32 bit word, 8 bit pages for each level
 Insert address 0x**F**E**F**F**F**E**C**2 mapping to frame 3

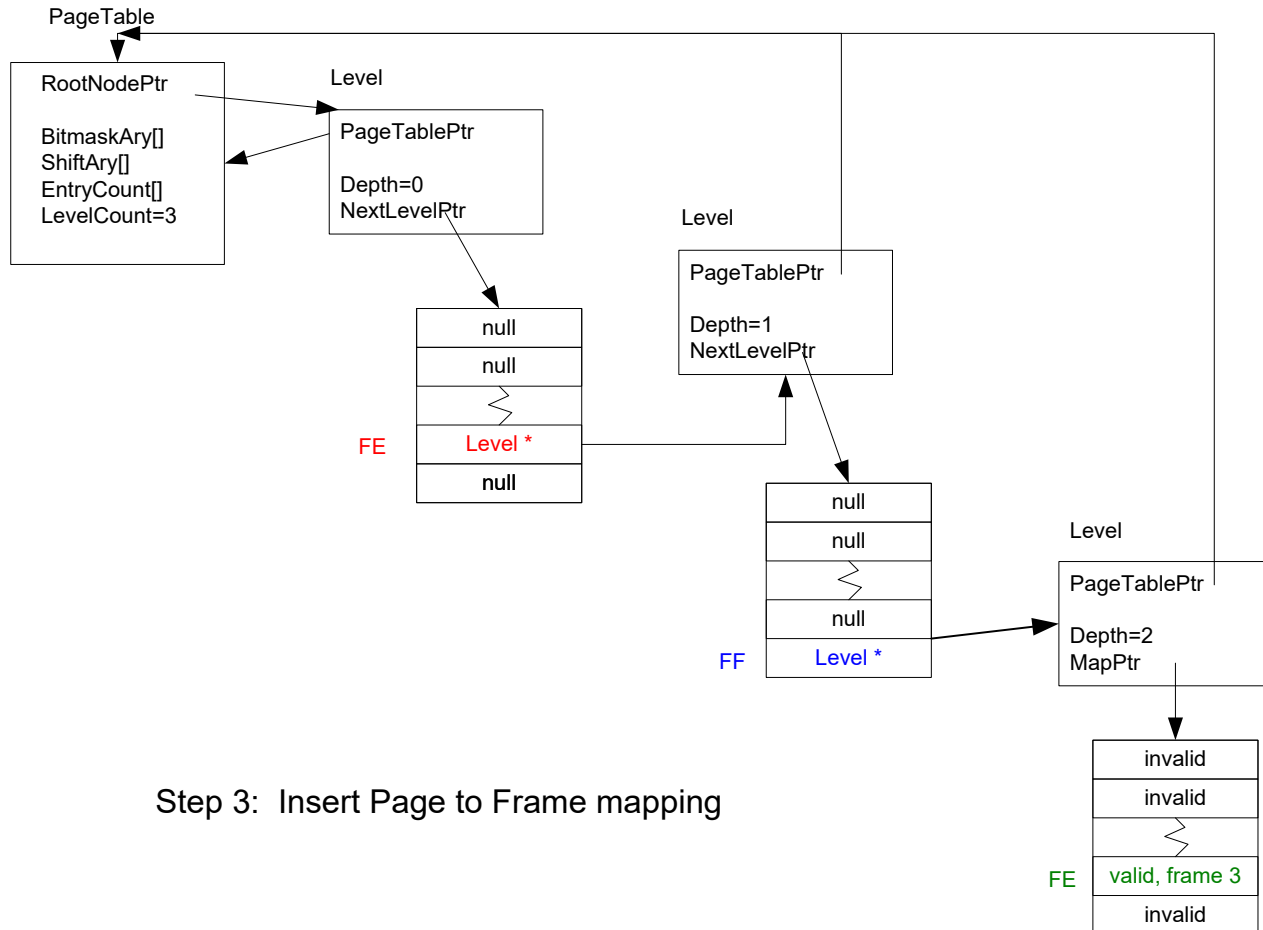


Inserting leaf nodes

- Next, we insert the level 2 node which is a leaf in a 3 level page table.
- This time, we allocate Maps instead of pointers to NextLevel.
- Initialize the pages to invalid.
- Set the level 2 page to valid and store the frame.

Page Insertion

Assume 32 bit word, 8 bit pages for each level
Insert address 0x**FE****FF****EC**2 mapping to frame 3

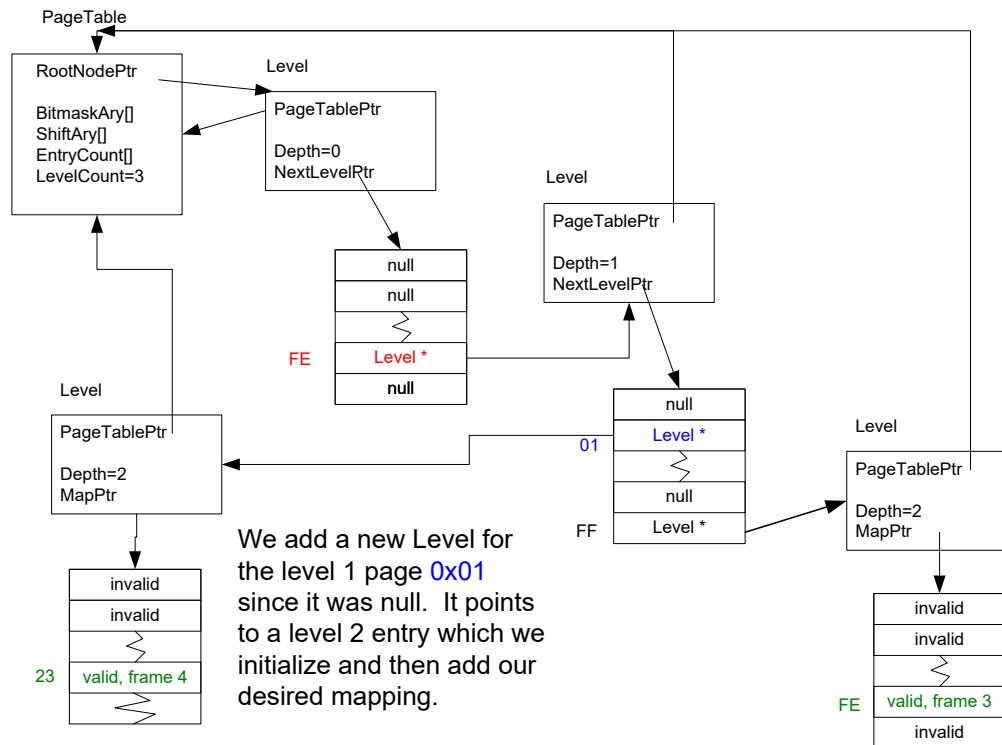


Another example

- Next, add a mapping between the page associated with address 0xFE0123C2 and frame 4.
- Pay attention to the fact that the level 0 page, 0xFE, already exists and note how the new entries are added.

Adding a second page

Assume 32 bit word, 8 bit pages for each level
Insert address 0xFE0123C2 mapping to frame 4



Page Insertion Pseudo-Code

```
PageInsert(PageTablePtr, Address, Frame) {  
    // C users, you would have to rename the 2nd PageInsert  
    // function since C cannot distinguish two functions with  
    // the same name and different signatures.  
    PageInsert(PageTablePtr->RootNodePtr, Address, Frame)  
}  
PageInsert(LevelPtr, Address, Frame) {  
    Find index into current page level  
    if leaf node(LevelPtr) {  
        Set appropriate page index to valid and store Frame  
    } else {  
        Create a new Level and set level to current depth + 1  
        Create an array of Level * or Map entries based upon the number of entries in  
        the new level and initialize to null/invalid as appropriate  
        PageInsert(pointer to new Level, Address, Frame)  
    }  
}
```