CIS 263 Introduction to Data Structures and Algorithms

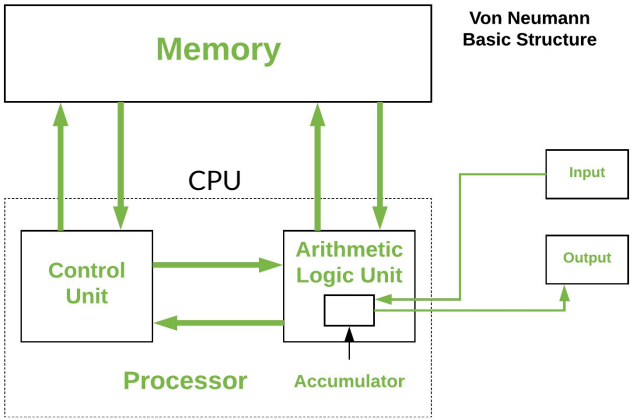
B-Trees

B-Tree

- A **B-tree** is a self-balancing tree.
- The B-tree generalizes BST, allowing more than two children.
- Unlike other self balancing (AVL Tree, RBT), the B-Tree is well suited for **storage systems** that read and write relatively large blocks of data, such as databases and file systems.

https://en.wikipedia.org/wiki/B-tree

Computer Architecture basics



https://www.geeksforgeeks.org/computer-organization-von-neumann-architecture/

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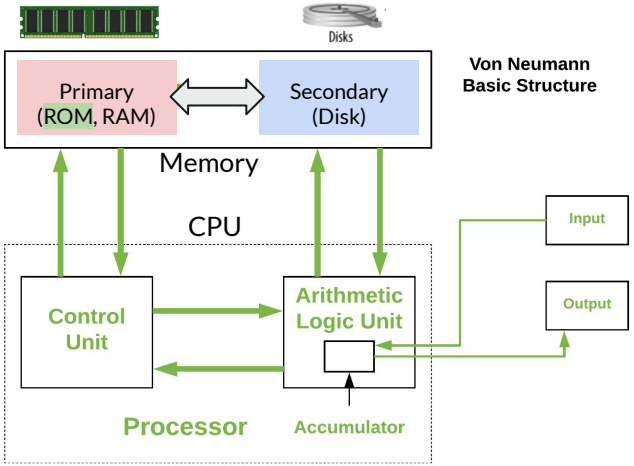

Von Neumann
Basic Structure

- In this course, our main focus will be mainly focused on the **memory management** part; more importantly the **primary memory**
- And **number of disk accesses** (latency delay)
- Through
  - Using appropriate data structures, and
  - Algorithms
- We are not doing any improvements over architecture etc.

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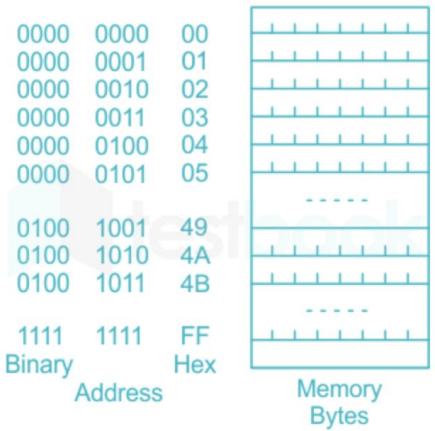
Memory, the concept of Array



- 8 bit memory (a simple case)

https://testbook.com/question-answer/a-memory-with-8-bit-data-bus-and-8-bit-address-bus--5e6e029ff60d5d4a3b0c5ce9

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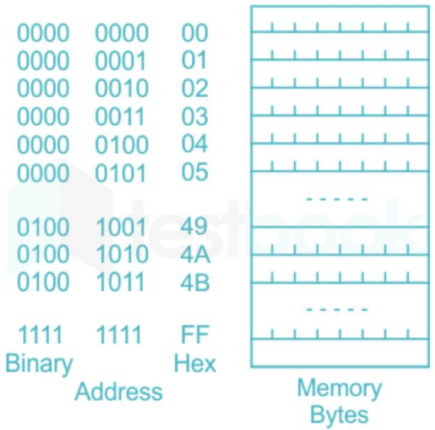

- 8 bit memory (a simple case)
- **What's the total memory size?**

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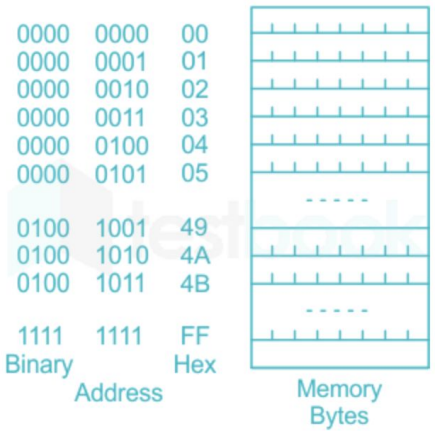

- 8 bit memory (a simple case)
- **What's the total memory size?**
  - **2^8 or 1024 byte**

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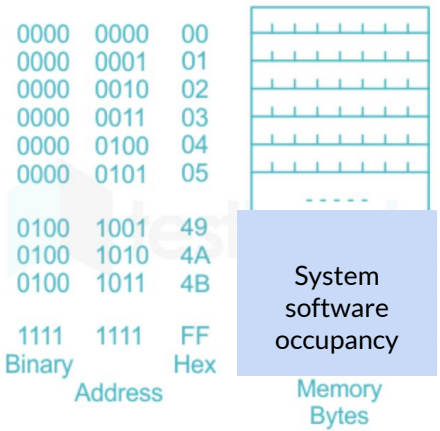

- 8 bit memory (a simple case)
- What's the total memory size?
  - 2^8 or 1024 byte
- **Addressing is inherent (consecutive, a sequence)**

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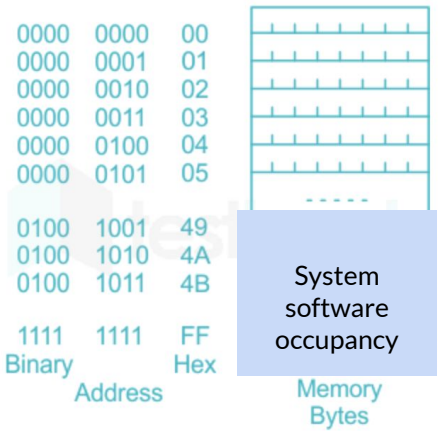

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- **Let's assume our system softwares reserved part of the memory like**

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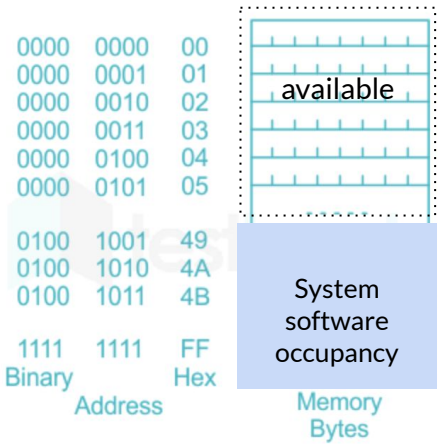

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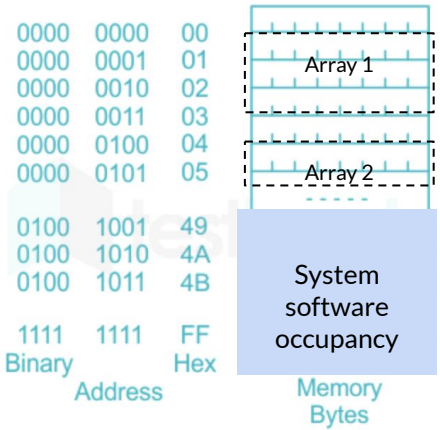
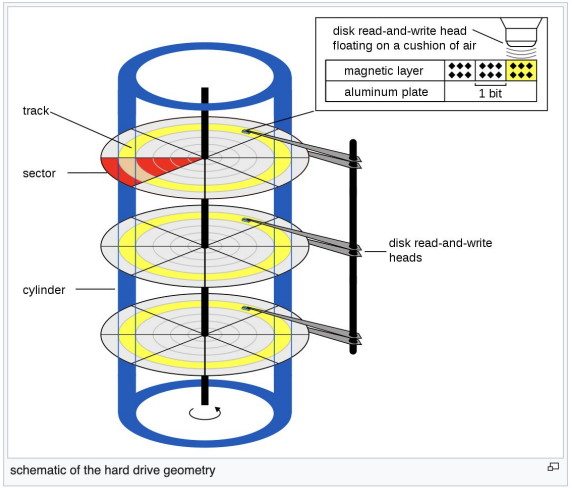


- Addressing is inherent (consecutive, a sequence)
- Let's assume our system softwares reserved part of the memory like
- **Array** (our first data structure) meaning holding a fixed block whether you use it or not.

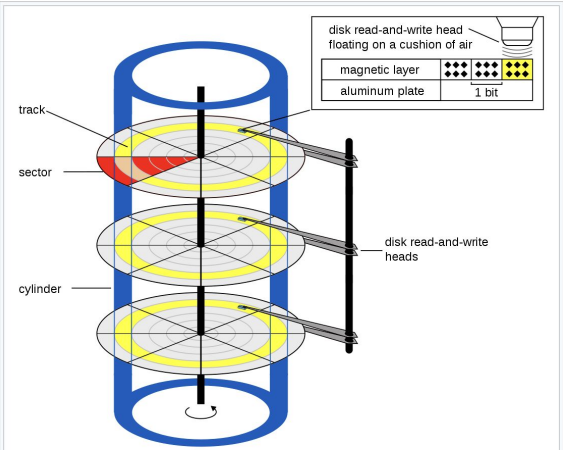
https://testbook.com/question-answer/a-memory-with-8-bit-data-bus-and-8-bit-address-bus--5e6e029ff60d5d4a3b0c5ce9

Disk: track, sector, block



schematic of the hard drive geometry

Disk: track, sector, block, offset



schematic of the hard drive geometry

It’s all about how to reduce number of disk accesses

Disk: track, sector, block, offset

An exercise:

- One student record requires 128 Byte
- **How many such records a block can store at max ?**

One student record requires 128 Byte

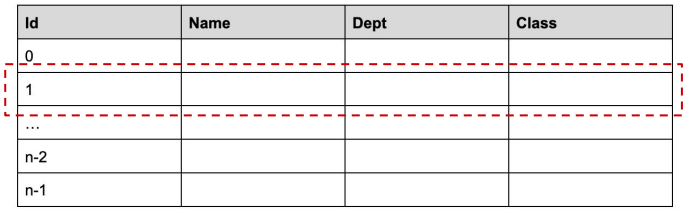
Id	Name	Dept	Class
0			
1			
…			
n-2			
n-1			

Disk: track, sector, block, offset

An exercise:

- One student record requires 128 Byte
- How many such records a block can store at max ?
- **512 / 128 = 4**

One student record requires 128 Byte



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Disk: track, sector, block, offset

An exercise:

- One student record requires 128 Byte
- How many such records a block can store at max ?
- 512 / 128 = 4
- **How many blocks you will require to store n=100 student records?**

One student record requires 128 Byte

Id	Name	Dept	Class
0			
1			
…			
n-2			
n-1			

Disk: track, sector, block, offset

An exercise:

- One student record requires 128 Byte
- How many such records a block can store at max ?
- 512 / 128 = 4
- How many blocks you will require to store n=100 student records?
- **100 / 4 = 25 blocks; right?**

One student record requires 128 Byte

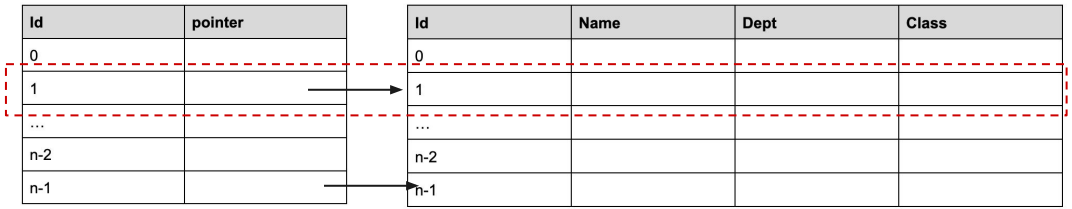
Id	Name	Dept	Class
0			
1			
…			
n-2			
n-1			

How about adding more content

An exercise:

- One student record requires 128 Byte
- 16 additional bytes for the pointer record
- **How many pointer records a Block can store?**

One student record requires 128 Bytes
One (id + pointer takes): 16 Bytes

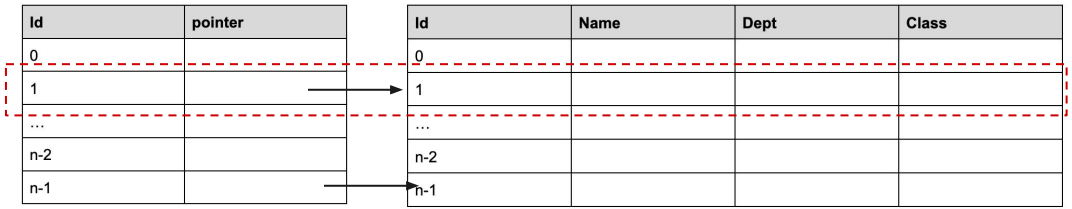


How about adding more content

An exercise:

- One student record requires 128 Byte
- 16 additional bytes for the pointer record
- How many pointer records a Block can store?
- **512 / 16 = 32**

One student record requires 128 Bytes
One (id + pointer takes): 16 Bytes

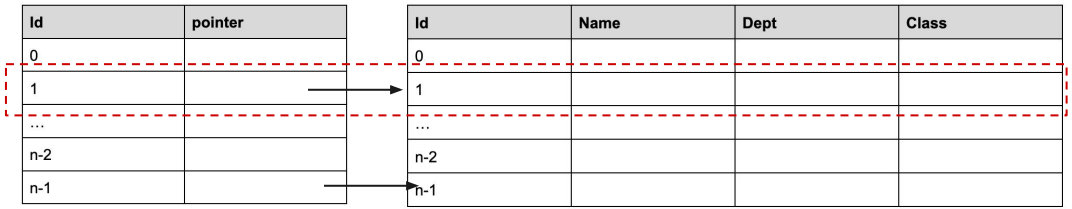


How about adding more content

An exercise:

- One student record requires 128 Byte
- 16 additional bytes for the pointer record
- How many pointer records a Block can store?
- 512 / 16 = 32
- **How many block you will require to query 100 records ?**

One student record requires 128 Bytes
One (id + pointer takes): 16 Bytes



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An exercise:

- One student record requires 128 Byte
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- How many pointer records a Block can store?
- 512 / 16 = 32
- How many block you will require to query 100 records ?
- **100 / 32 = ~ 4 (max)**

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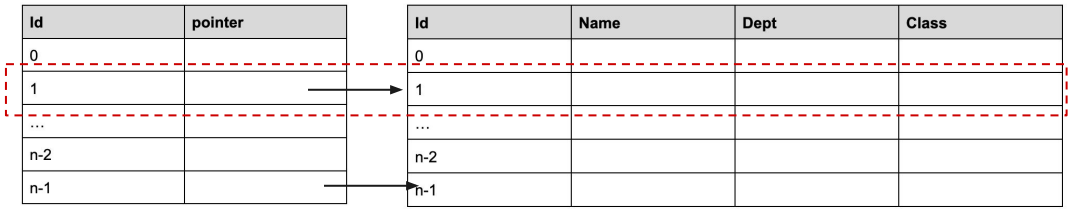
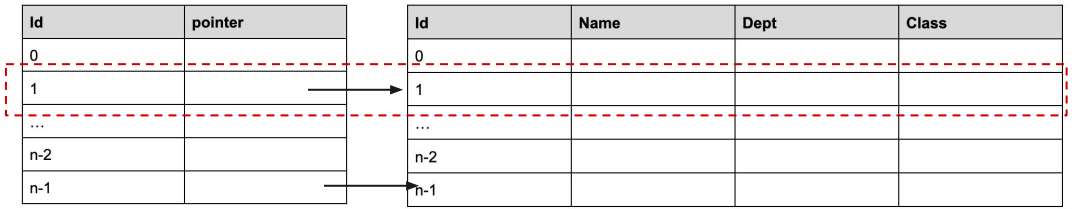


How about adding more content

An exercise:

- One student record requires 128 Byte
- 16 additional bytes for the pointer record
- How many pointer records a Block can store?
- 512 / 16 = 32
- How many block you will require to query 100 records ?
- 100 / 32 = ~ 4 (max)
- **So we reduced from 25 - > 4 Block accesses; right?**
- **This is the general idea of database indexing.**

One student record requires 128 Bytes
One (id + pointer takes): 16 Bytes



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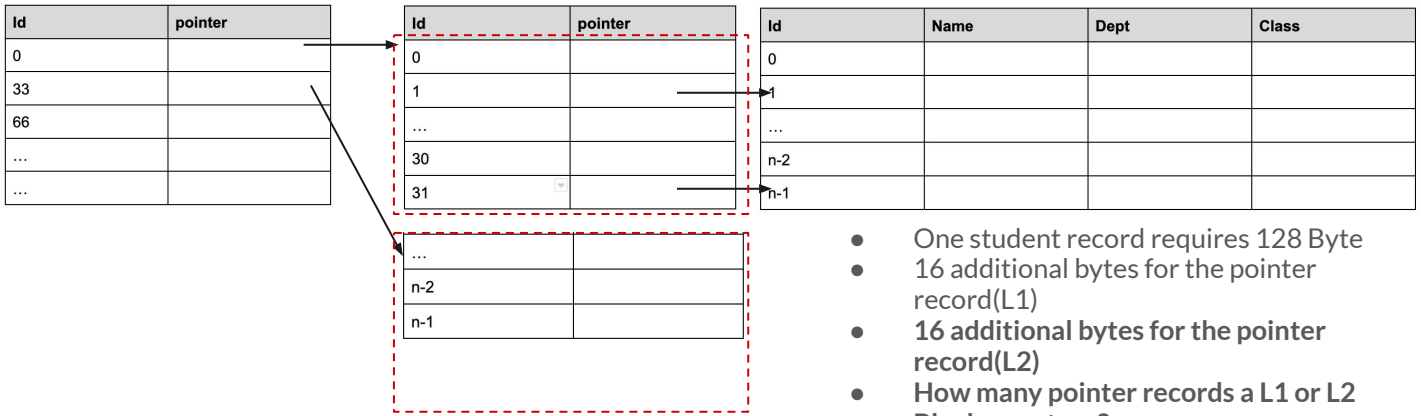
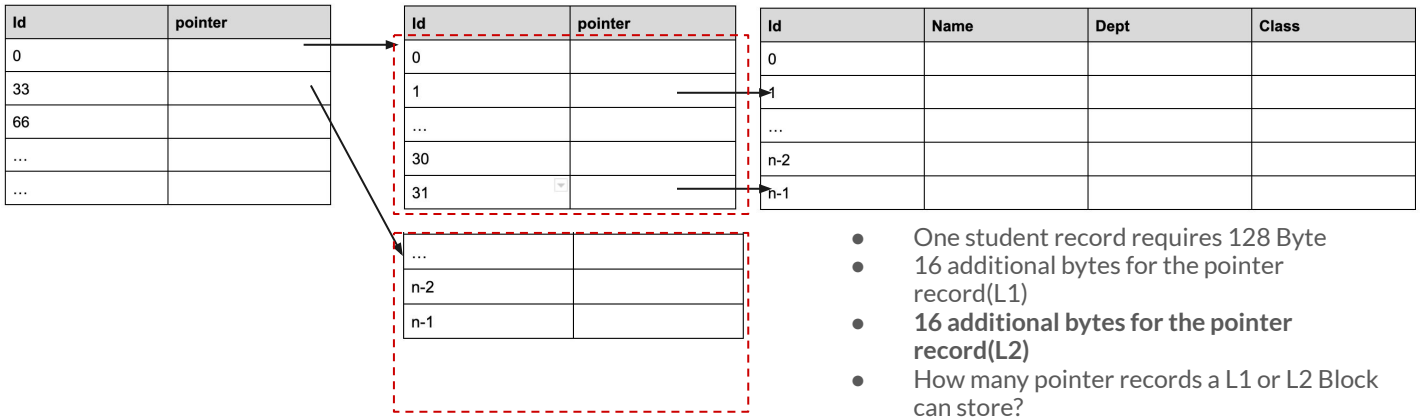


- One student record requires 128 Byte
- 16 additional bytes for the pointer record(L1)
- **16 additional bytes for the pointer record(L2)**
- **How many pointer records a L1 or L2 Block can store?**

How about adding more content

One student record requires 128 Bytes
One (id + pointer takes): 16 Bytes



- One student record requires 128 Byte
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- **16 additional bytes for the pointer record(L2)**
- How many pointer records a L1 or L2 Block can store?
- **512**

How about adding more content

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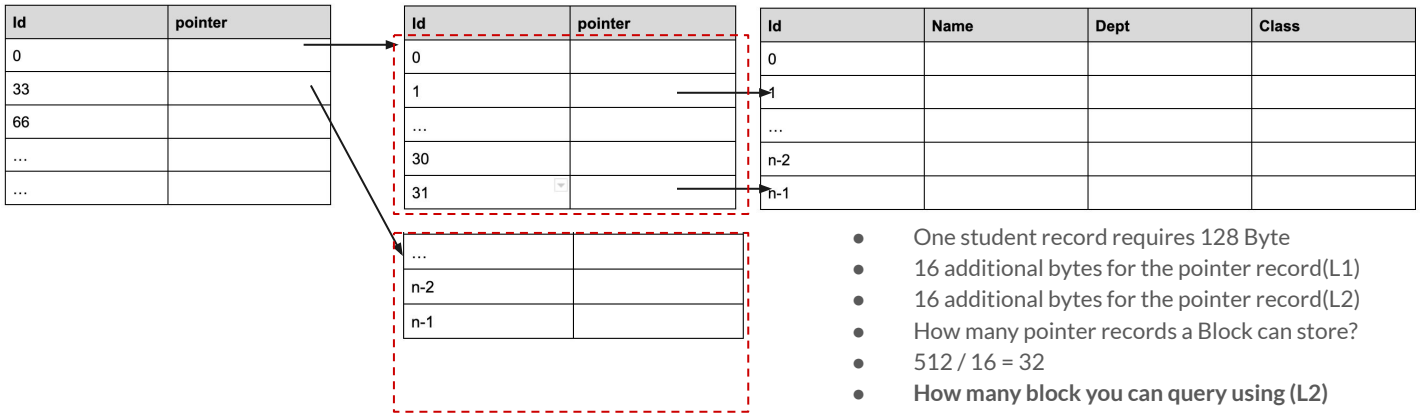

- One student record requires 128 Byte
- 16 additional bytes for the pointer record(L1)
- 16 additional bytes for the pointer record(L2)
- How many pointer records a Block can store?
- 512 / 16 = 32
- **How many block you can query using (L2)**

How about adding more content

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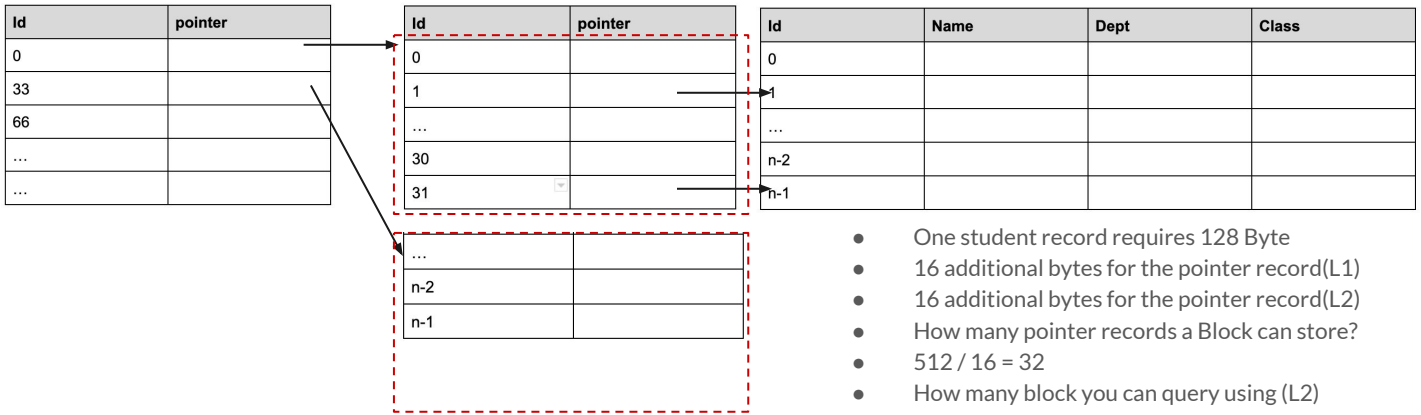


- One student record requires 128 Byte
- 16 additional bytes for the pointer record(L1)
- 16 additional bytes for the pointer record(L2)
- How many pointer records a Block can store?
- 512 / 16 = 32
- How many block you can query using (L2)
- **32 * 32 = 1024**

m-way tree

- ***m-1*** keys
- ***m*** children

B-tree

- Every node has ***m/2 (ceil)*** children at least
- Root has minimum ***2 children***
- All leaves at same level
- Bottom up method

Generating a m(3)-way B-Tree

- M = 3
- Max 3-1 = 2 keys per node

45

Input sequence: 45

Generating a m(3)-way B-Tree

- M = 3
- Max 3-1 = 2 keys per node

35, 45

Input sequence: 45, 35

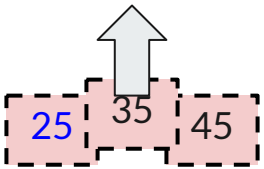
Generating a m(3)-way B-Tree

- M = 3
- Max 3-1 = 2 keys per node
- Limit exceeds

25, 35, 45

Input sequence: 45, 35, 25

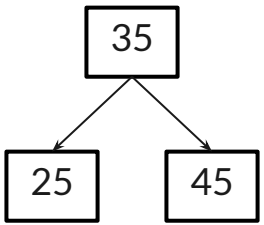
Generating a m(3)-way B-Tree



- M = 3
- Max 3-1 = 2 keys per node
- Limit exceeds
- Split and adjust levels

Input sequence: 45, 35, 25

Generating a m(3)-way B-Tree



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Input sequence: 45, 35, 25

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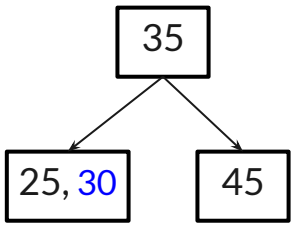
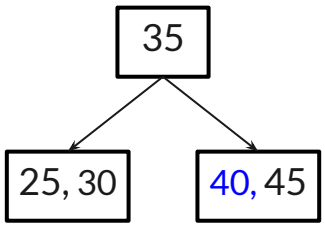


- M = 3
- Max 3-1 = 2 keys per node

Input sequence: 45, 35, 25, 30

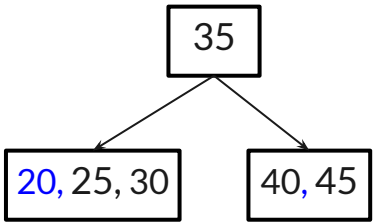
Generating a m(3)-way B-Tree



- M = 3
- Max 3-1 = 2 keys per node

Input sequence: 45, 35, 25, 30, 40

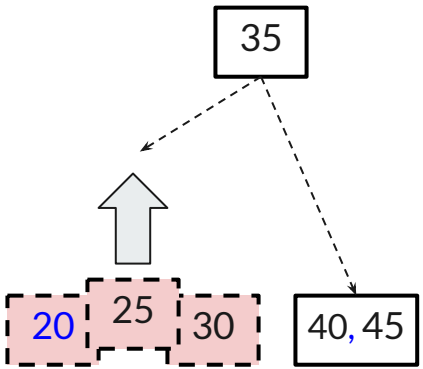
Generating a m(3)-way B-Tree



- M = 3
- Max 3-1 = 2 keys per node
- Limit exceeds
- Split and adjust levels

Input sequence: 45, 35, 25, 30, 40, 20

Generating a m(3)-way B-Tree



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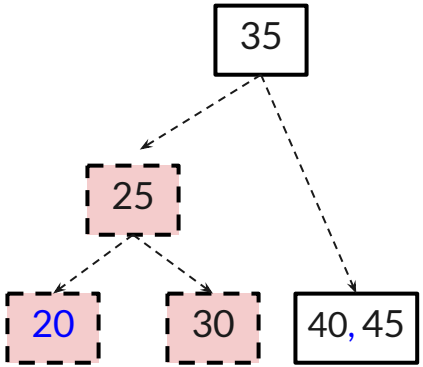

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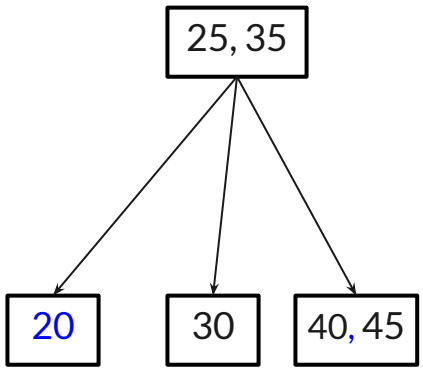

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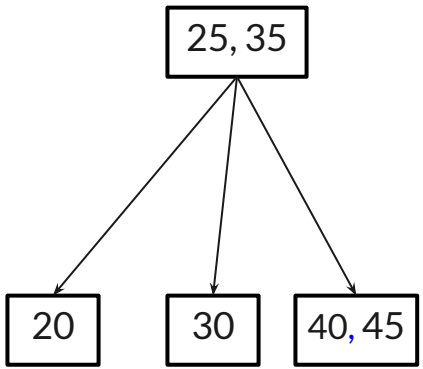
Input sequence: 45, 35, 25, 30, 40, 20

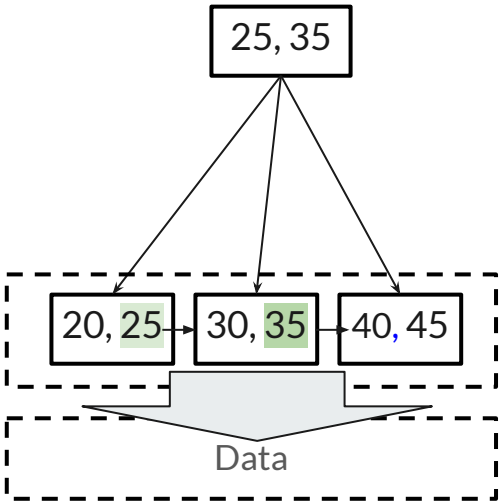
Generating a m(3)-way B-Tree



- M = 3
- Max 3-1 = 2 keys per node

Input sequence: 45, 35, 25, 30, 40, 20

B+ Tree



- M = 3
- Max 3-1 = 2 keys per node
- All keys (both internal and leaf nodes) are available at the leaf level (duplicate copies of root/intermediate nodes at the leaf level)
- Leaf nodes contain data pointers