Data-Intensive Computing Systems

Data Access from Disks

Shivnath Babu
Outline

• Disks
• Data access from disks
• Software-based optimizations
  – Prefetching blocks
  – Choosing the right block size
Focus on: “Typical Disk”

Terms: Platter, Head, Cylinder, Track
       Sector (physical), Block (logical), Gap
Block Address:

- Physical Device
- Cylinder #
- Surface #
- Start sector #
Disk Access Time (Latency)

I want block X

? block X in memory
Access Time =
Seek Time +
Rotational Delay +
Transfer Time +
Other
Seek Time

Average value: 10 ms → 40 ms
Rotational Delay

Head Here

Block I Want
Average Rotational Delay

R = 1/2 revolution

Example: R = 8.33 ms (3600 RPM)
Transfer Rate: \( t \)

- \( t: 1 \rightarrow 100 \text{ MB/second} \)
- transfer time: block size \( t \)
Other Delays

• CPU time to issue I/O
• Contention for controller
• Contention for bus, memory

“Typical” Value: 0
• So far: Random Block Access
• What about: Reading “Next” block?
If we do things right ...

Time to get \( t \) = \text{Block Size} + \text{Negligible}

- skip gap
- switch track
- once in a while, next cylinder
<table>
<thead>
<tr>
<th>Rule of Thumb</th>
<th>Random I/O: Expensive</th>
<th>Sequential I/O: Much less</th>
</tr>
</thead>
</table>

- Ex: 1 KB Block
  - Random I/O: ~ 20 ms.
  - Sequential I/O: ~ 1 ms.
Cost for **Writing** similar to **Reading**

.... unless we want to verify!
To Modify Block:

(a) Read Block
(b) Modify in Memory
(c) Write Block
[(d) Verify?]
A Synthetic Example

• 3.5 in diameter disk
• 3600 RPM
• 1 surface
• 16 MB usable capacity (16 X 2^{20})
• 128 cylinders
• seek time: average = 25 ms.

  adjacent cylinders = 5 ms.
• 1 KB blocks = sectors
• 10% overhead between sectors
• capacity = 16 MB = \((2^{20})16 = 2^{24}\) bytes
• # cylinders = 128 = \(2^7\)
• bytes/cyl = \(2^{24}/2^7 = 2^{17} = 128\) KB
• blocks/cyl = 128 KB / 1 KB = 128
3600 RPM → 60 revolutions / sec
→ 1 rev. = 16.66 msec.

One track:

Time over useful data: (16.66)(0.9) = 14.99 ms.
Time over gaps: (16.66)(0.1) = 1.66 ms.
Transfer time 1 block = 14.99/128 = 0.117 ms.
Trans. time 1 block + gap = 16.66/128 = 0.13 ms.
Burst Bandwidth

1 KB in 0.117 ms.

\[ BB = \frac{1}{0.117} = 8.54 \text{ KB/ms} \]

or

\[ BB = 8.54 \text{ KB/ms} \times 1000 \text{ ms/1 sec} \times \frac{1 \text{ MB}}{1024 \text{ KB}} = \frac{8540}{1024} = 8.33 \text{ MB/sec} \]
Sustained bandwidth (over track)
128 KB in 16.66 ms.

SB = 128/16.66 = 7.68 KB/ms

or

SB = 7.68 x 1000/1024 = 7.50 MB/sec.
$T_1 = \text{Time to read one random block}$

$T_1 = \text{seek + rotational delay + TT}$

$= 25 + \frac{16.66}{2} + .117 = 33.45 \text{ ms.}$
A Back of Envelope Calculation

• Suppose it takes 25 ms to read one 1 KB block
• 10 tuples of size 100 bytes each fit in 1 block
• How much time will it take to read a table containing 1 Million records (say, Amazon’s customer database)?
Suppose DBMS deals with 4 KB blocks

\[ T_4 = 25 + \frac{16.66}{2} + 0.117 \times 1 \]
\[ + (0.130) \times 3 = 33.83 \text{ ms} \]

[Compare to \( T_1 = 33.45 \text{ ms} \)]
\[ T_T = \text{Time to read a full track} \]

(start at any block)

\[ T_T = 25 + \left( \frac{0.130}{2} \right) + 16.66^* = 41.73 \text{ ms} \]

\[ \sqrt{\text{to get to first block}} \]

* Actually, a bit less; do not have to read last gap.
Outline

• Disks
• Data access from disks
• Software-based optimizations
  – Prefetching blocks
  – Choosing the right block size
Software-based Optimizations (in Disk controller, OS, or DBMS Buffer Manager)

- Prefetching blocks
- Choosing the right block size
- Some others covered in Garcia-Molina et al. book
Prefetching Blocks

- Exploits locality of access
  - Ex: relation scan
- Improves performance by hiding access latency
- Needs extra buffer space
  - Double buffering
Block Size Selection?

- Big Block $\rightarrow$ Amortize I/O Cost

Unfortunately...

- Big Block $\Rightarrow$ Read in more useless stuff!
Tradeoffs in Choosing Block Size

- Small relations?
- Update-heavy workload?
- Difficult to use blocks larger than track
- Multiple block sizes