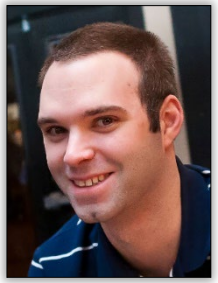
The Ins and Outs of SQL Server Data Compression

Bob Pusateri

About Bob Pusateri



Microsoft
CERTIFIED
Master

SQL Server 2008

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bobpusateri

MVP
Microsoft®
Most Valuable
Professional

Specialties:

- Performance Tuning
- Very Large Databases
- SQL Server Storage Engine
- Cloud Architecture
- Big Data
- Teaching/Mentoring/Helping

ChiSQL

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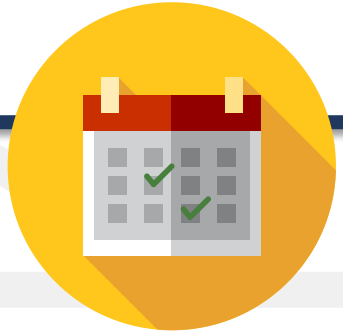
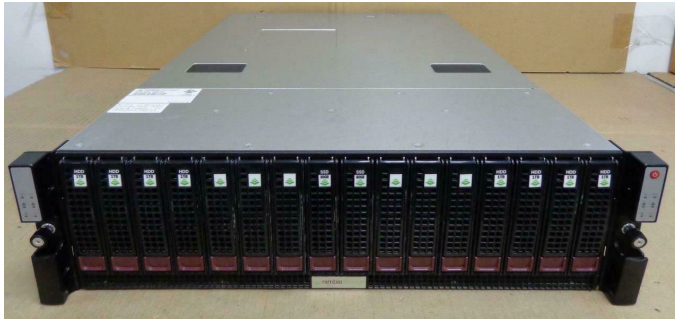
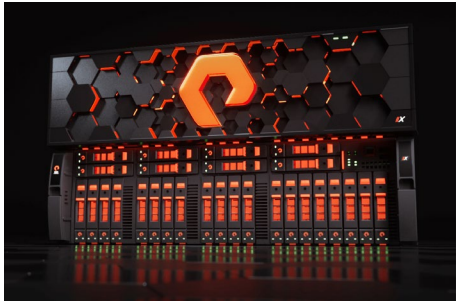
Agenda



- Compression Basics/Primer
- Row & Page Compression
- Columnstore Compression
- Questions

Why Compress?

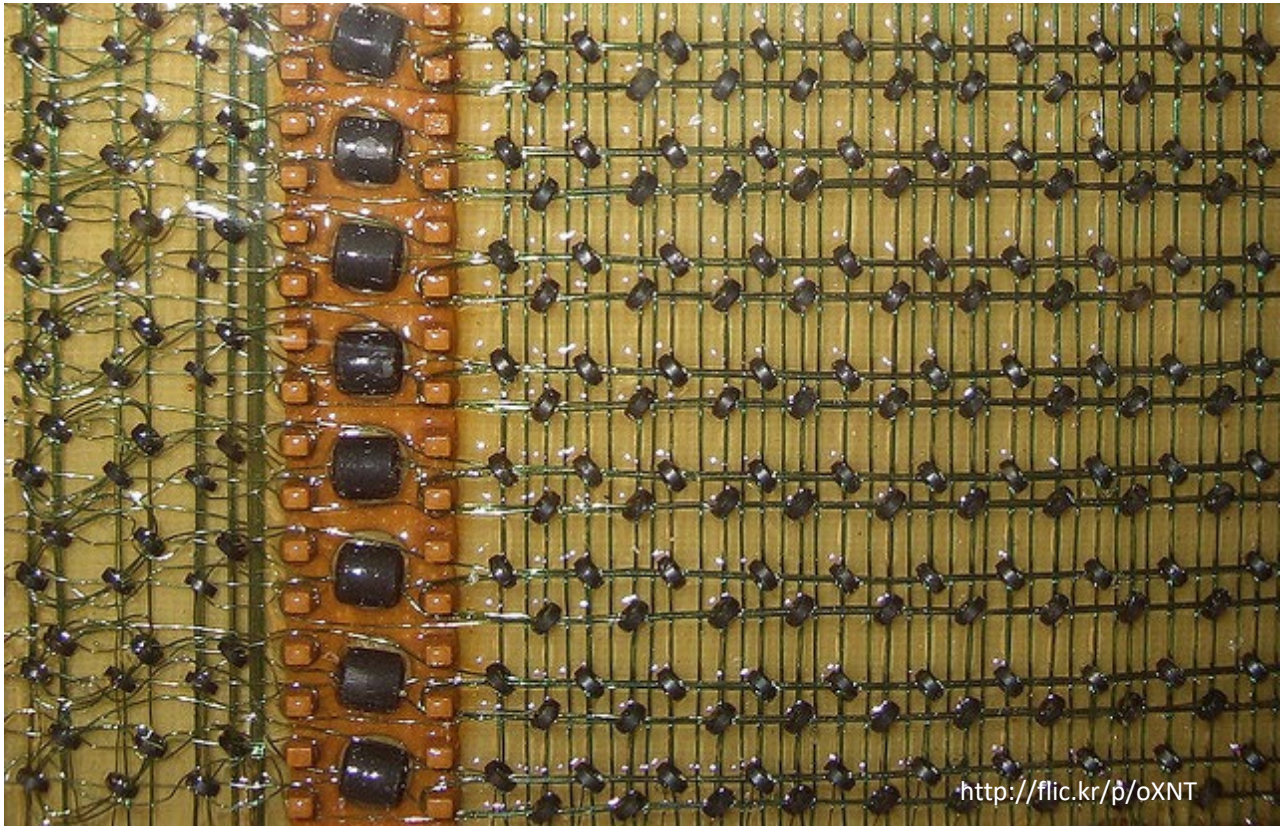




Why Compress?

http://flic.kr/p/6tGK8E

Why Compress?



Why Compress?

Lossy Compression

Lossless Compression

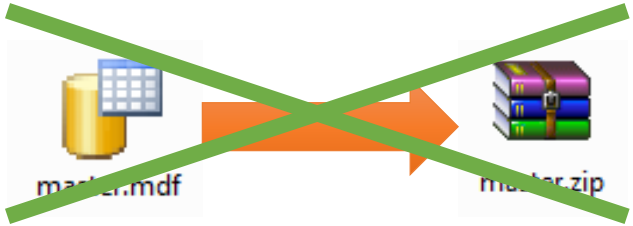
http://flic.kr/p/5BbUo2

Lossless Compression

- Huffman Coding
  - Most common data coded with fewest number of bytes
- Statistical Modeling
  - LZ77/LZ78
  - LZW/LZMA/gzip
  - Create a dictionary of most common patterns
  - Reference them with pointers where appropriate

SQL Server Access Patterns

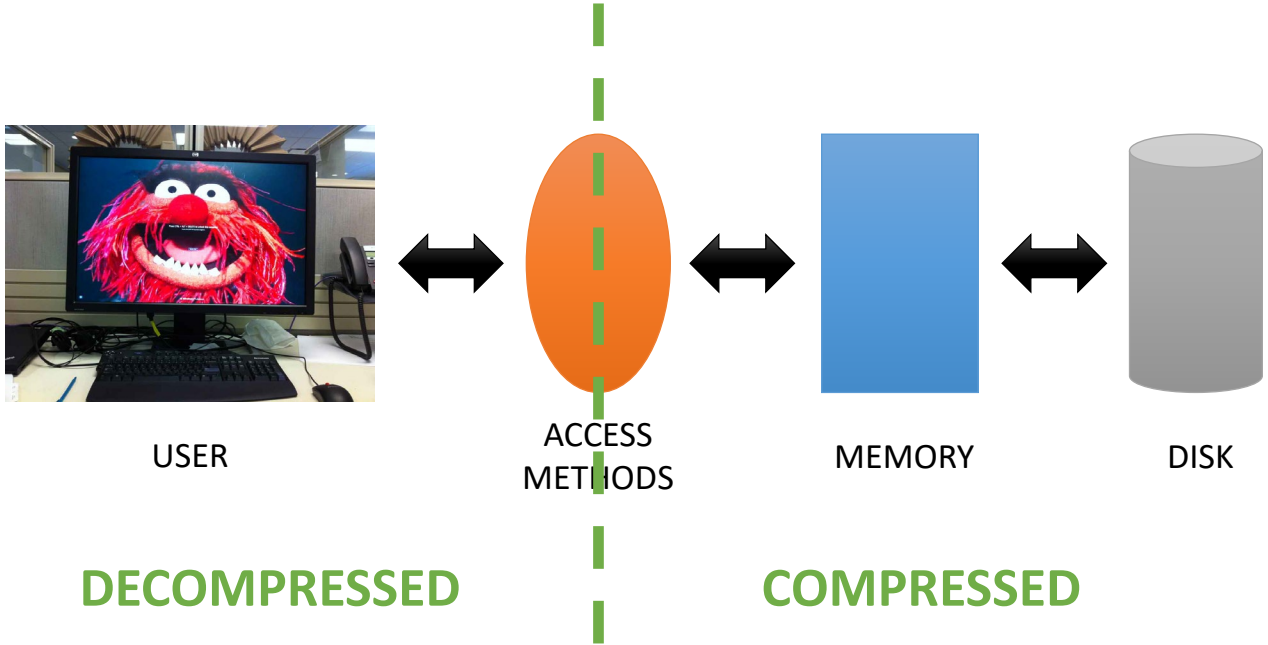
- Why not just zip* the .mdf file?



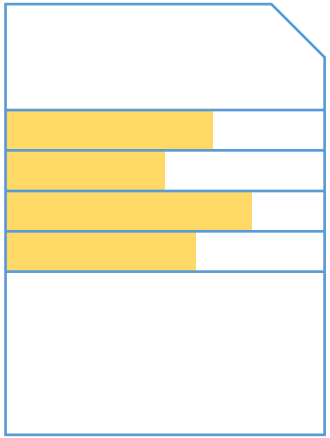
Database I/O is:

- Generally very random
- Generally very small (8KB pages, 64KB extents)
- NEED TO BALANCE COMPRESSION RATIO & SPEED!

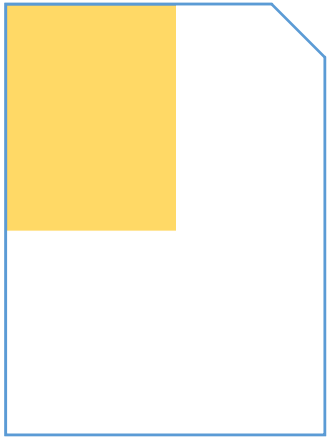
Where Data Compression Occurs



Compression Types



ROW



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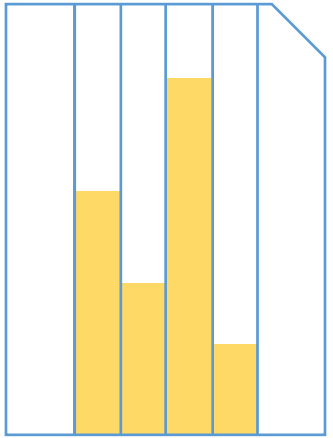


COLUMNSTORE

Row Compression

ROW Compression

- “Only use the space you need” compression
- Fixed-length numeric data becomes variable-length
  - Only uses necessary bytes
  - INT with value of 5 will use 1 byte instead of 4
- Fixed-length character data also variable-length
  - CHAR(100) value ‘Stu’ uses 3 bytes, not 100
- NULL & zero values take no space
- Variable-length metadata overhead reduced
  - New record structure
  - 2 bytes per column without compression
  - 4 bits per column with compression
  - For variable-length columns <= 8 bytes
  - “Column Descriptors”

http://flic.kr/p/7f7Nb9

ROW Compression

- Has no effect on smallest datatypes
  - TINYINT, SMALLDATETIME, DATE, TIME
- Does help BIT columns
  - 4 columns can be shrunk to 4 bits (instead of 8/8)
- Unicode character data (nchar/nvarchar) MAY BE compressed
  - Uses SCSU algorithm
  - Only if compression has an advantage
  - nvarchar(max) not compressed at all

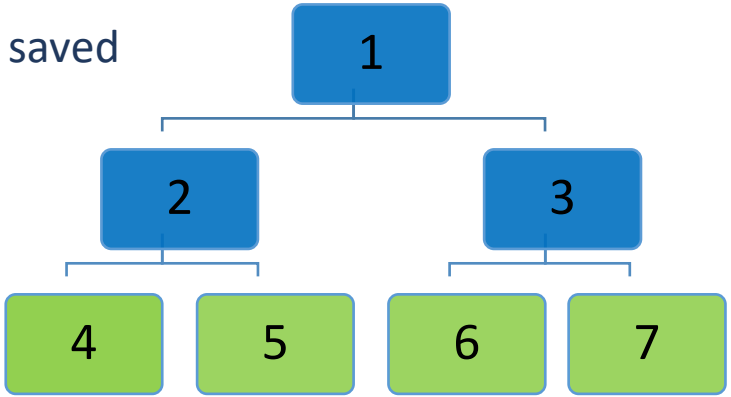
ROW Compression

ID SMALLINT		FirstName CHAR(8)							
92		S	A	M					
4346		N	I	C	K				
120		M	I	C	H	E	L	L	E

Page Compression

PAGE Compression

- Has 3 components (applied in this order)
  - ROW compression
  - Column prefix compression
  - Column dictionary compression
- Adds a “CI” (compression information) structure to each page
- May not be applied to every page
  - Only utilized on pages where space can be saved
- Applies only to leaf-level pages

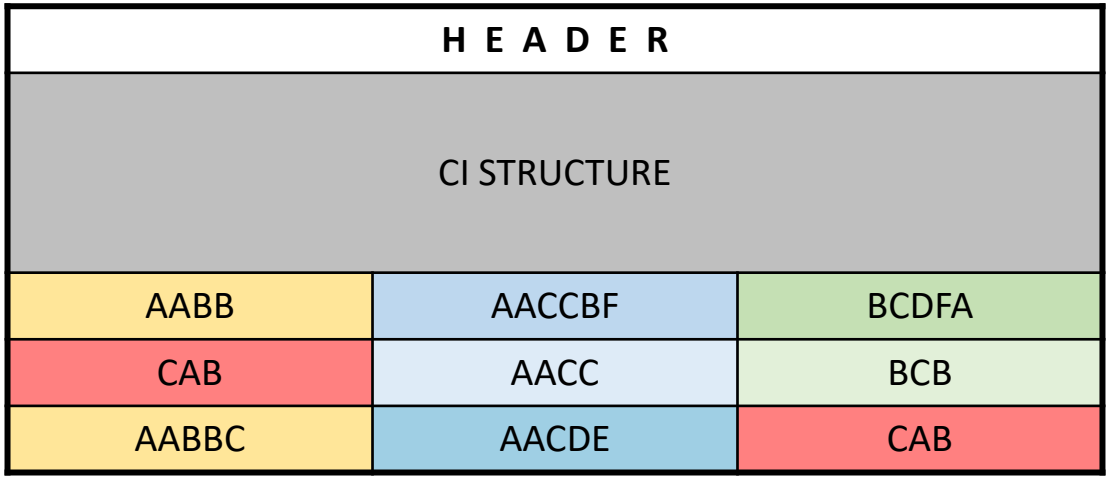


PAGE Compression (prefix)

- Prefix is in terms of byte values (type agnostic)
- Largest, most common prefix stored in “anchor record” in CI structure
- Row values are stored in terms of the anchor value

```
0x012368FFB8
0x012367FFB8
```

PAGE Compression (prefix)



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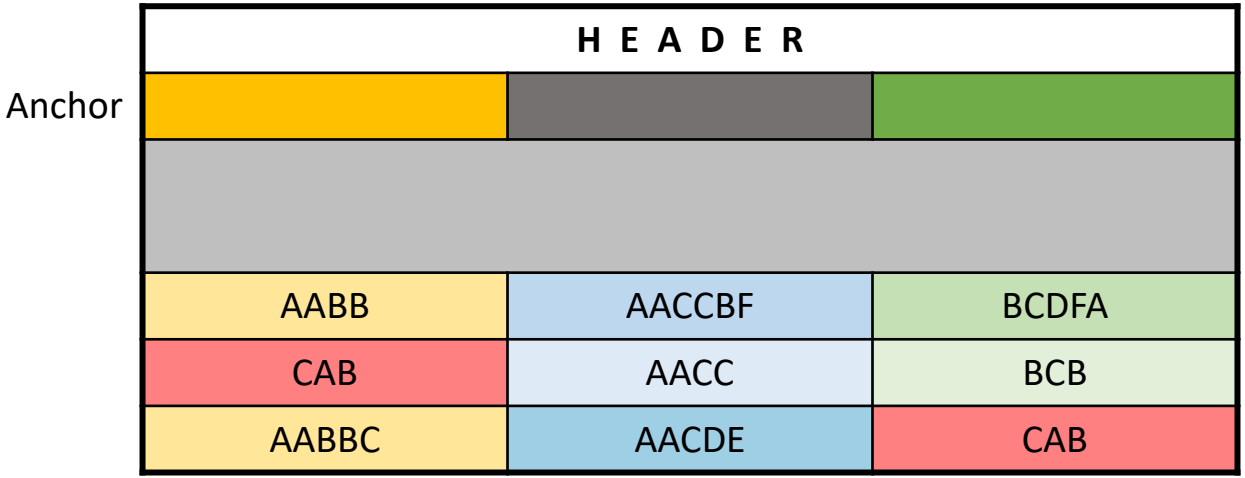

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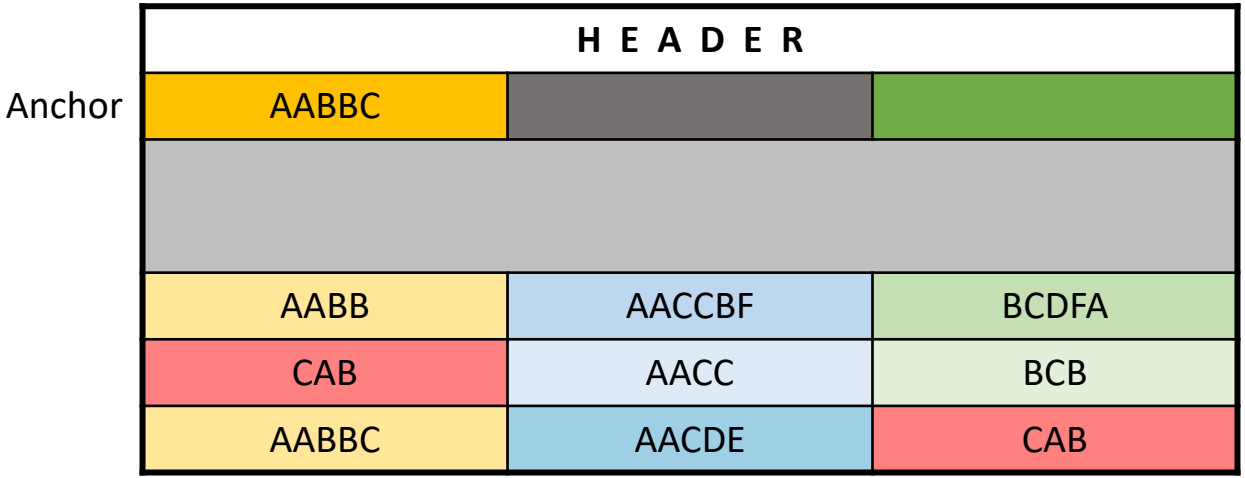

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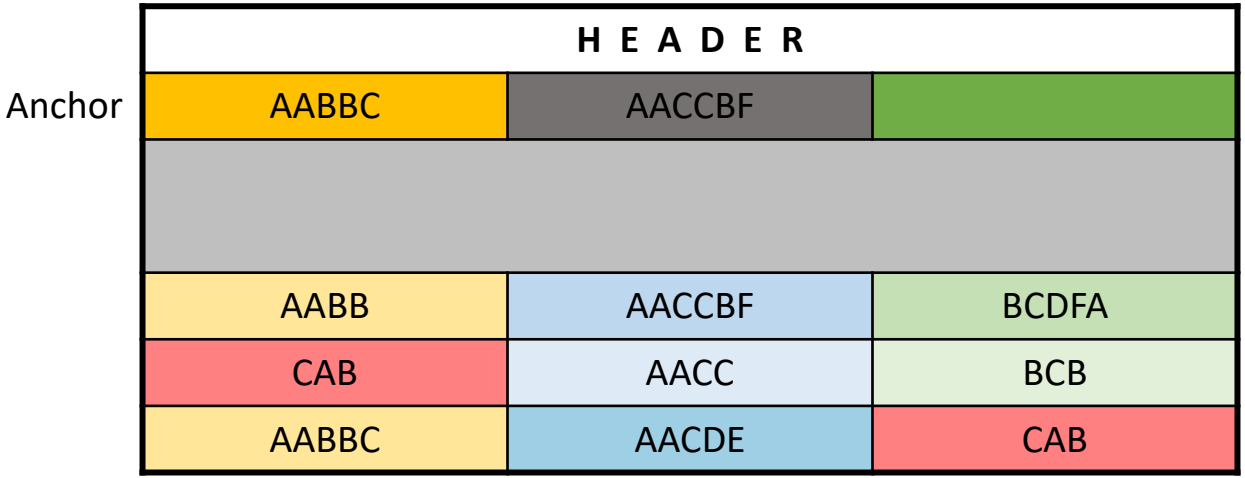

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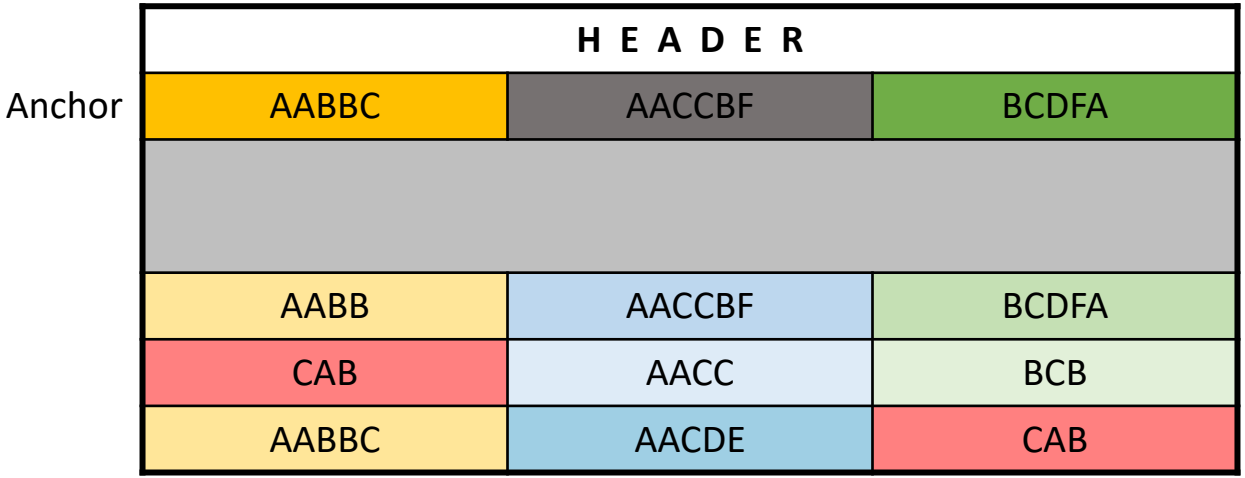

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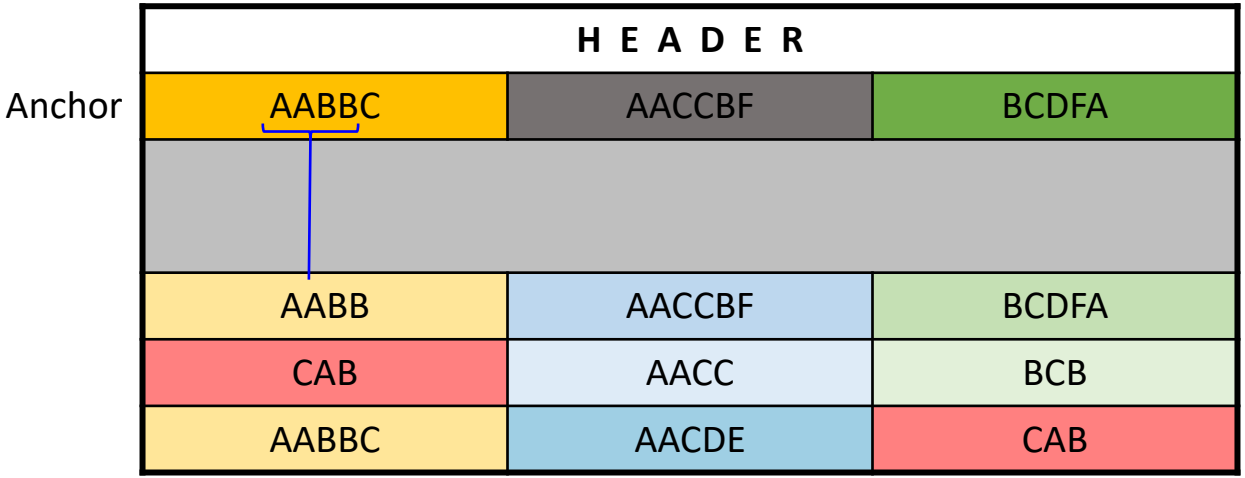

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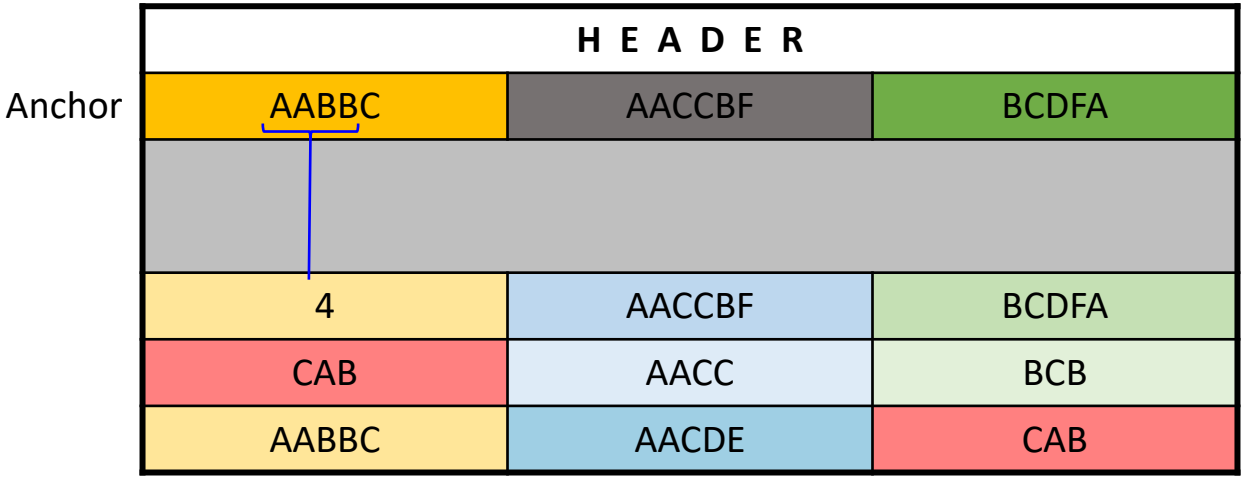

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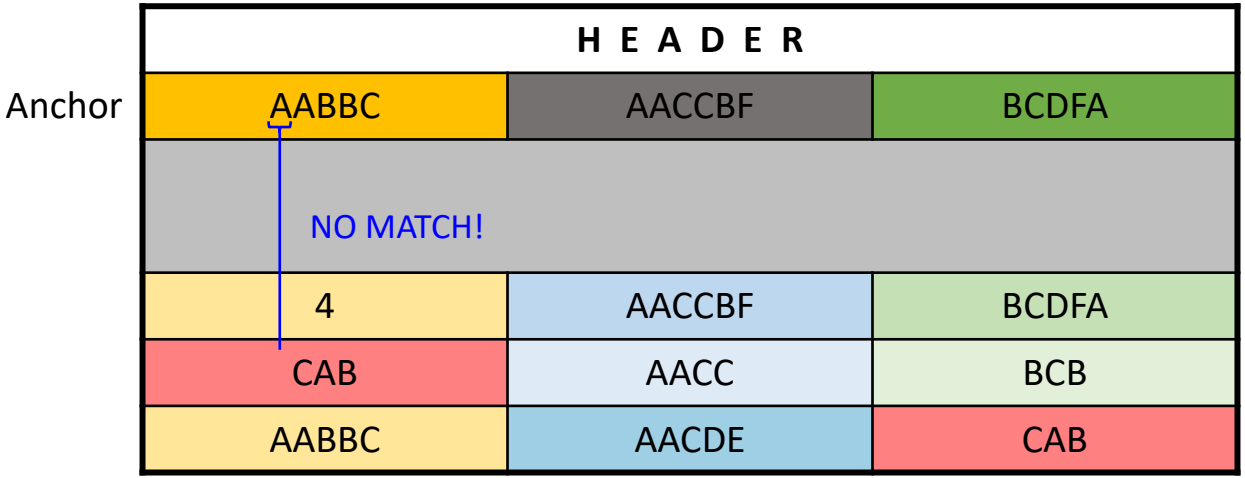

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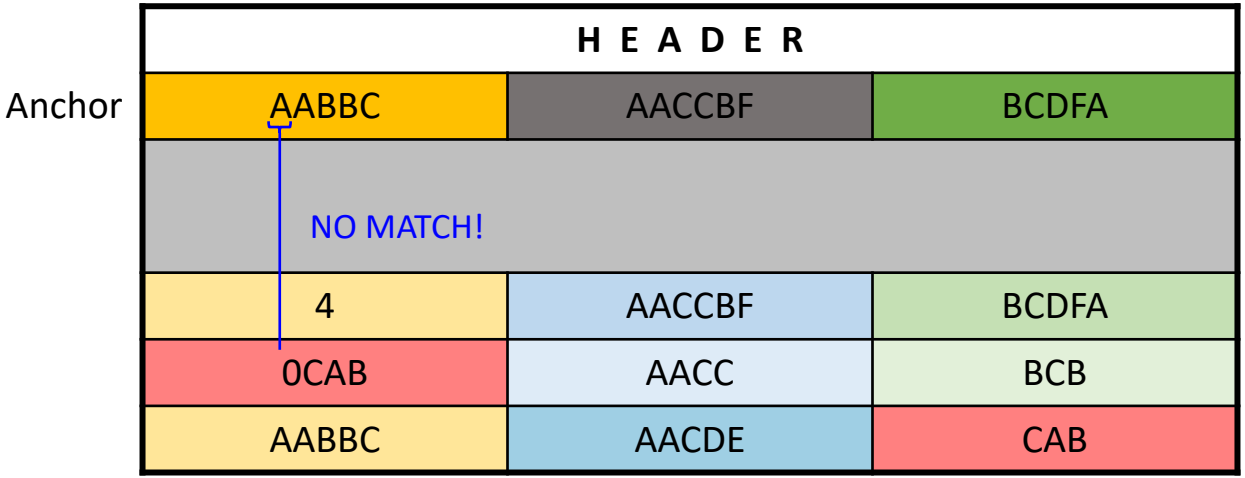

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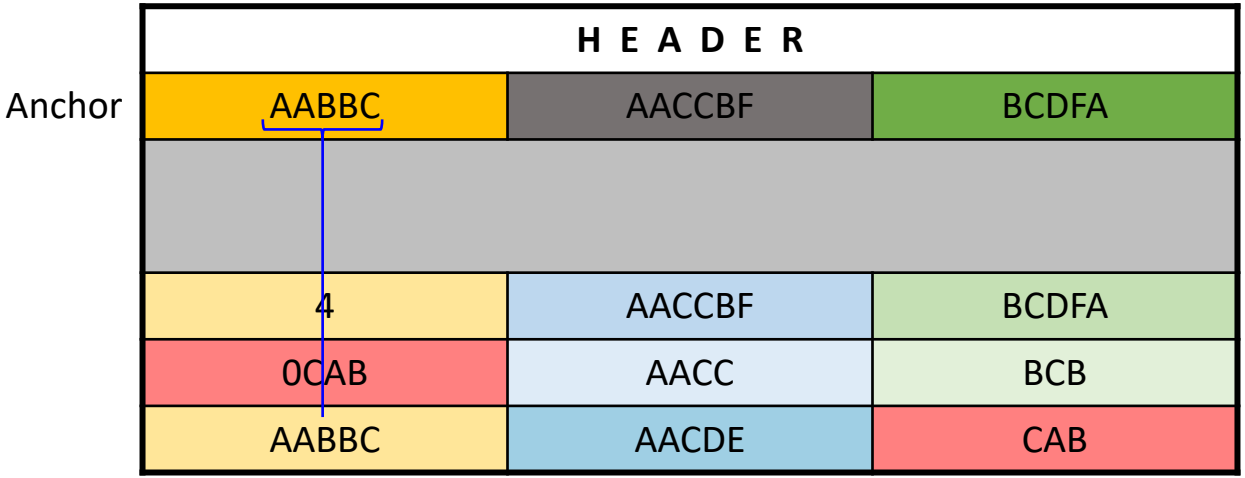

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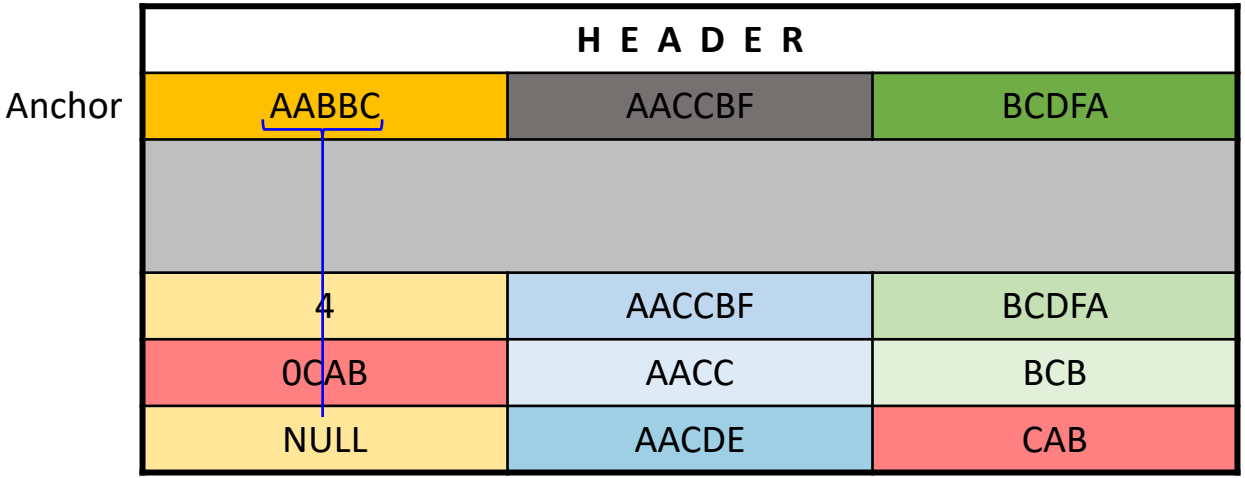

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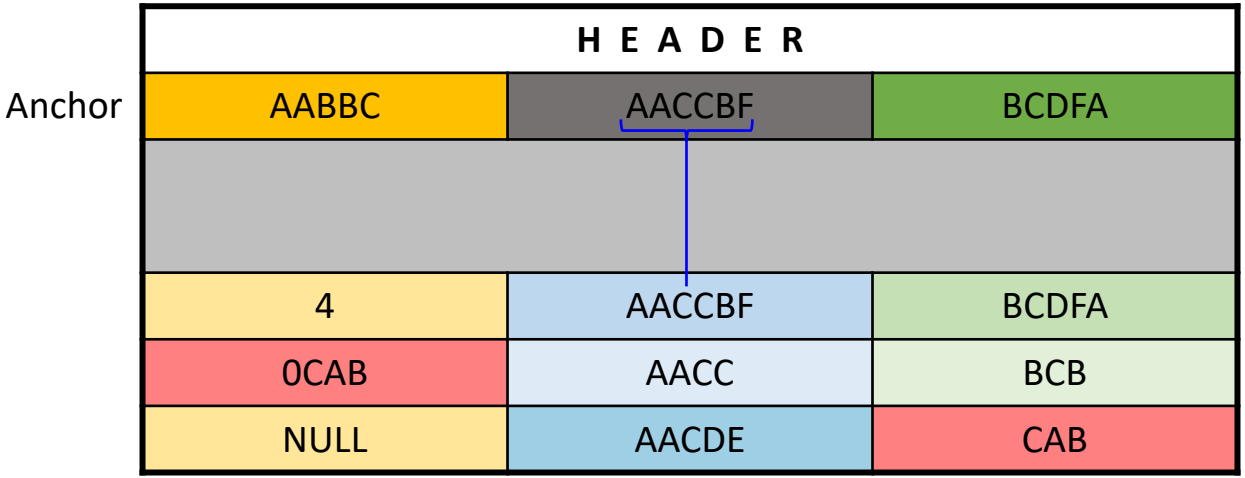

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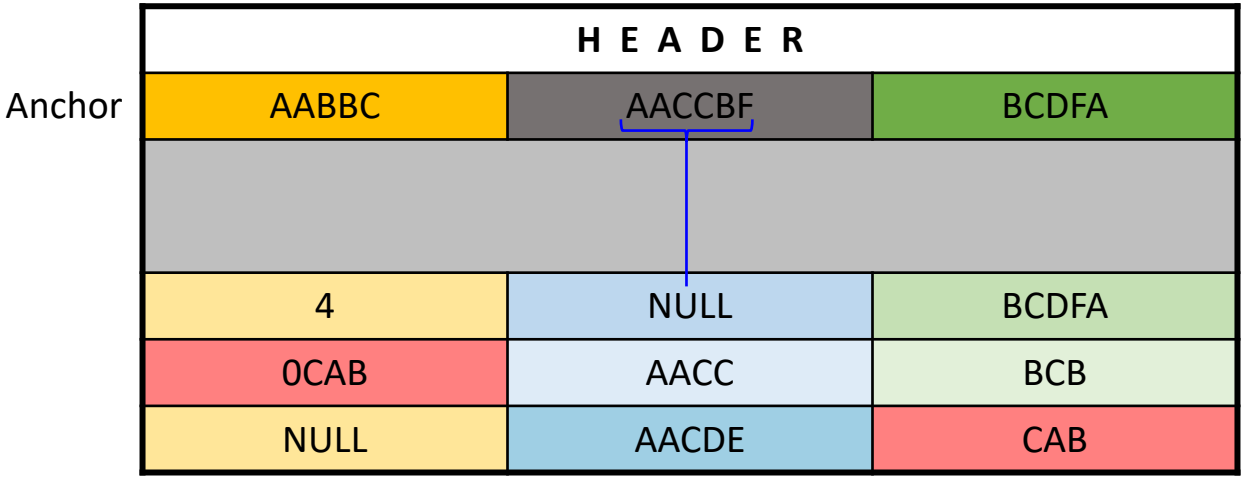

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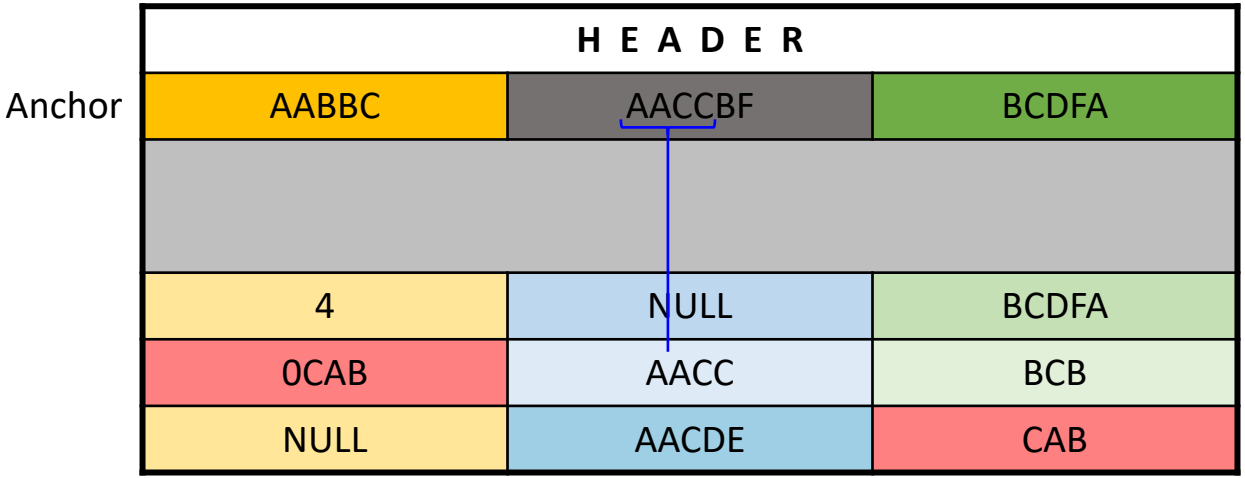

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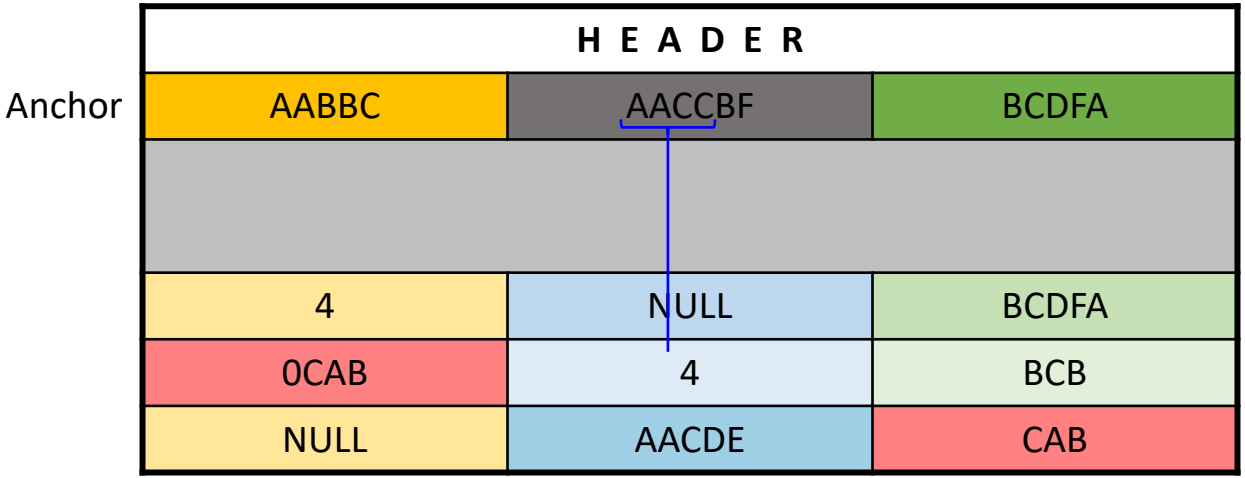

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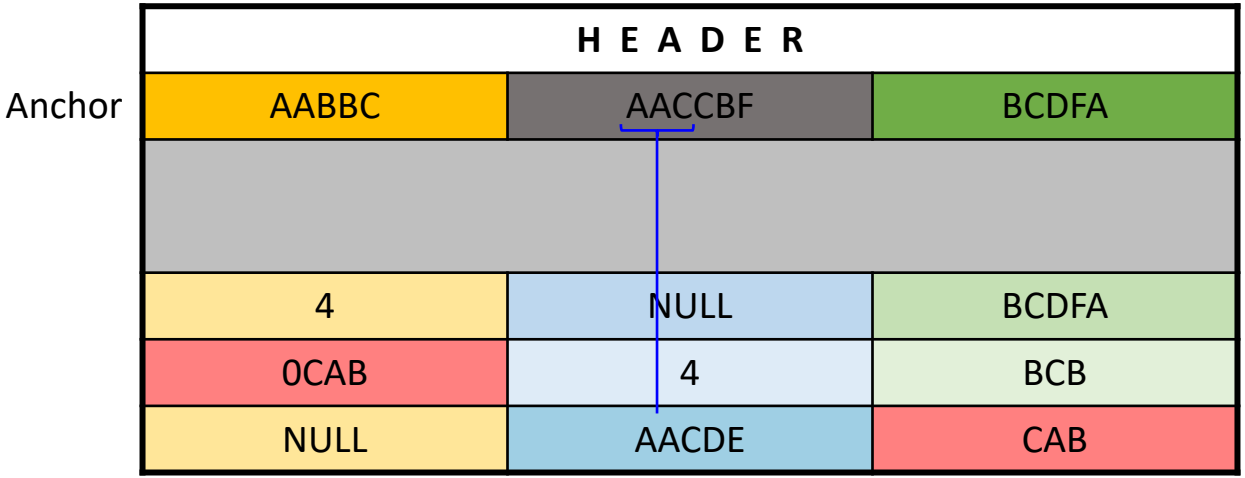

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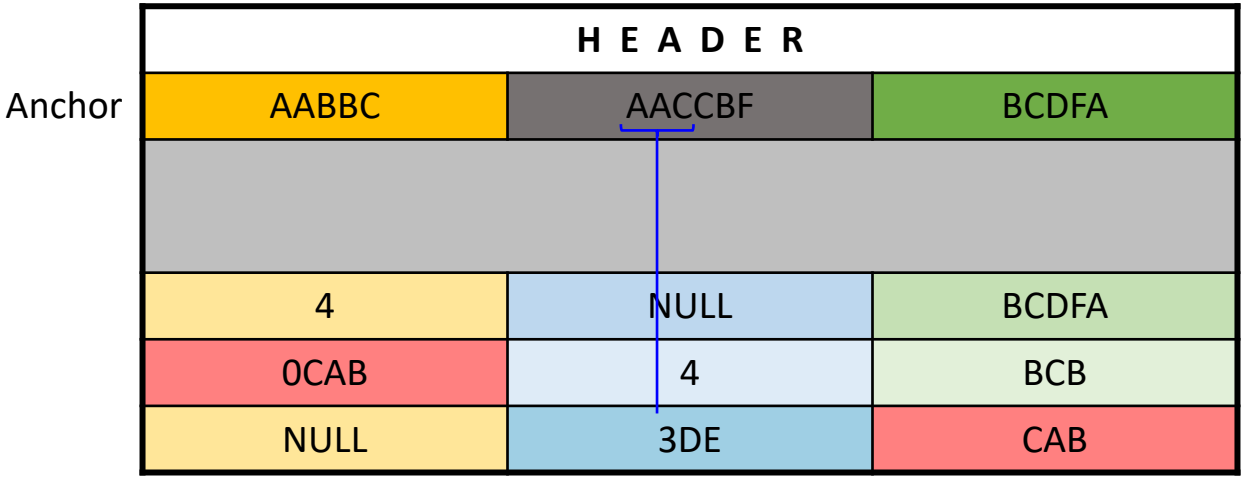

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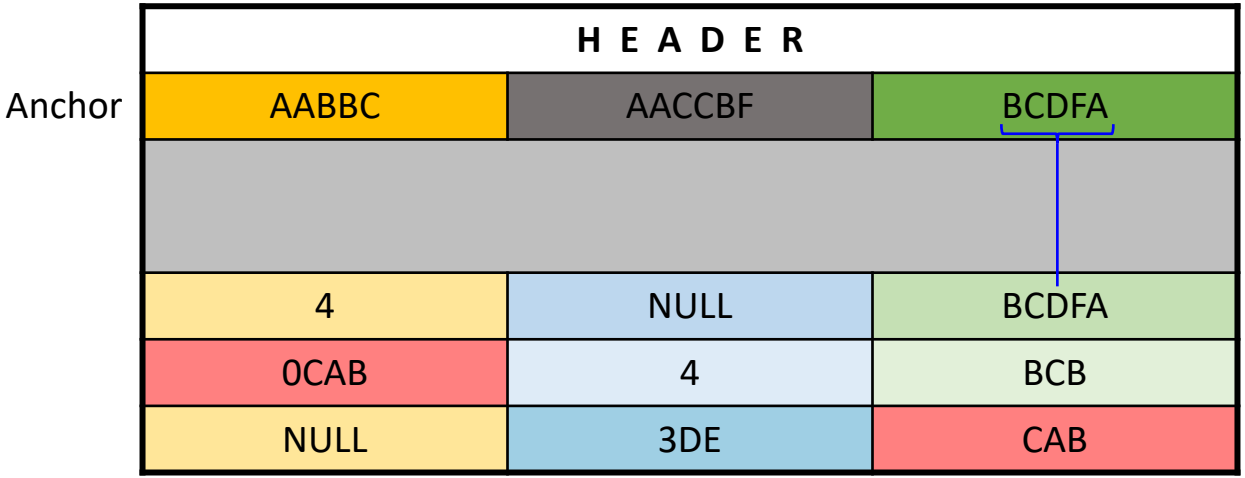

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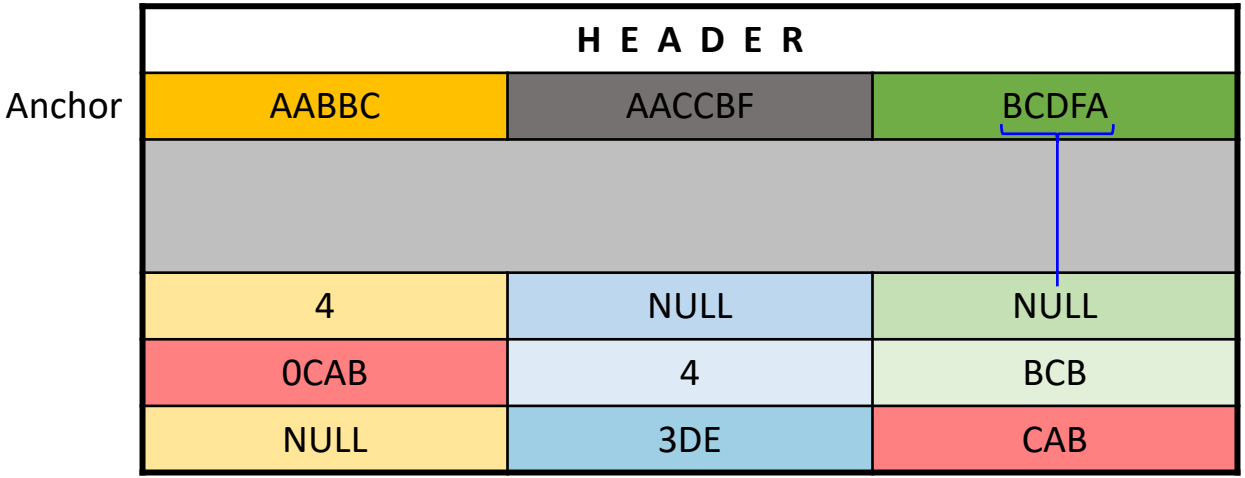

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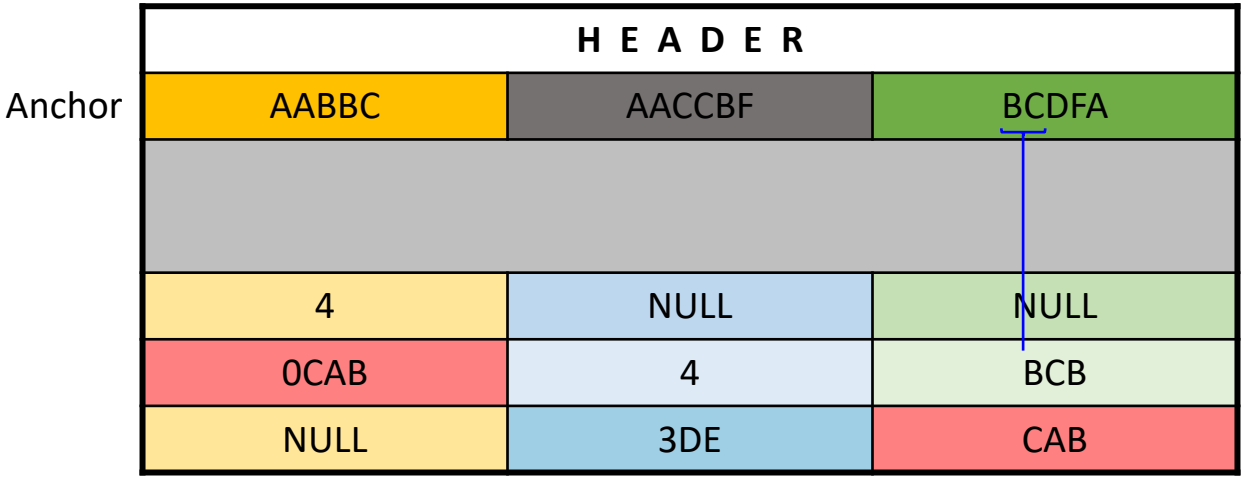

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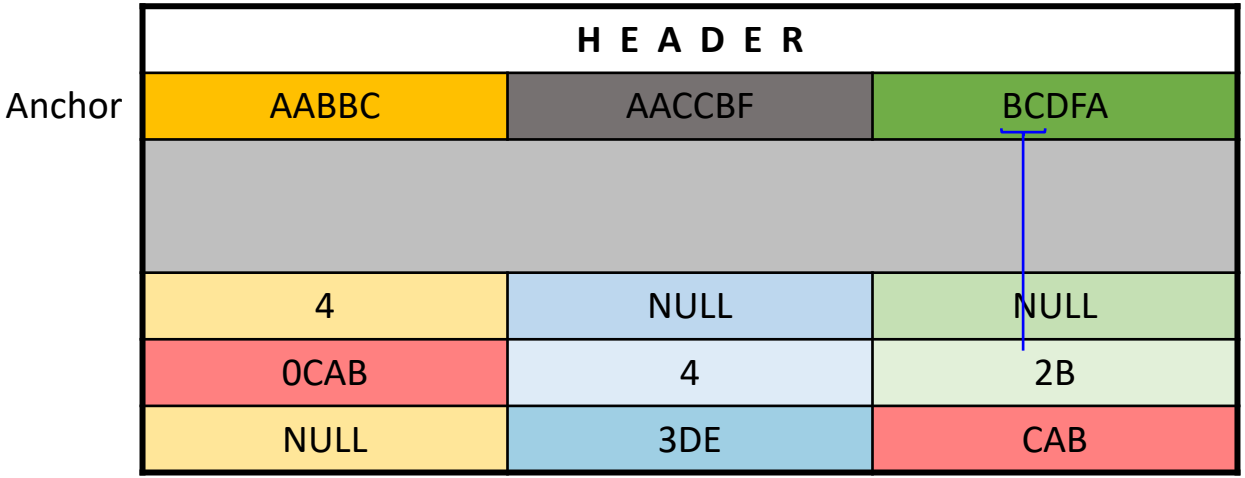

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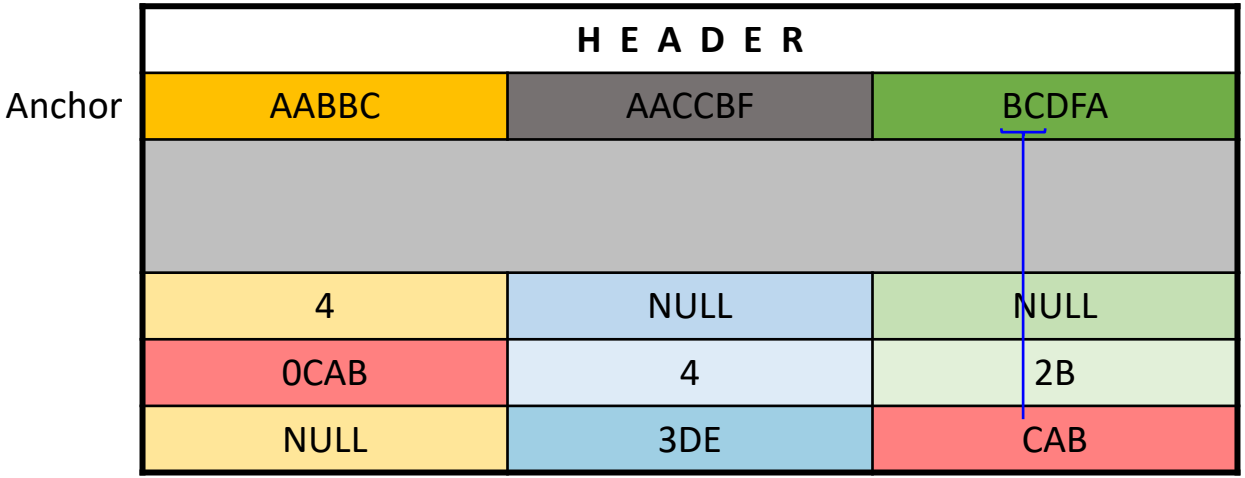

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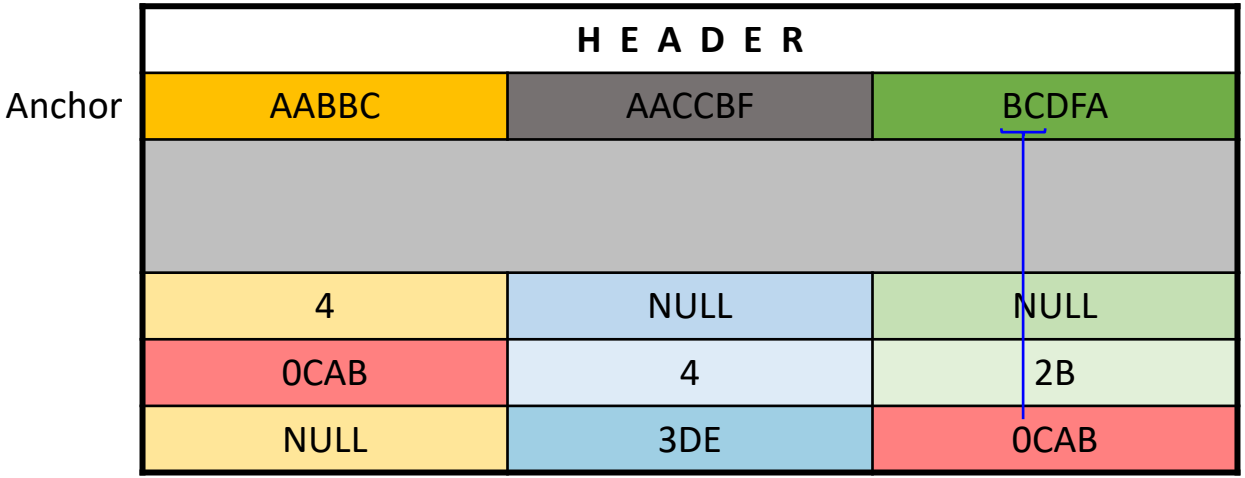

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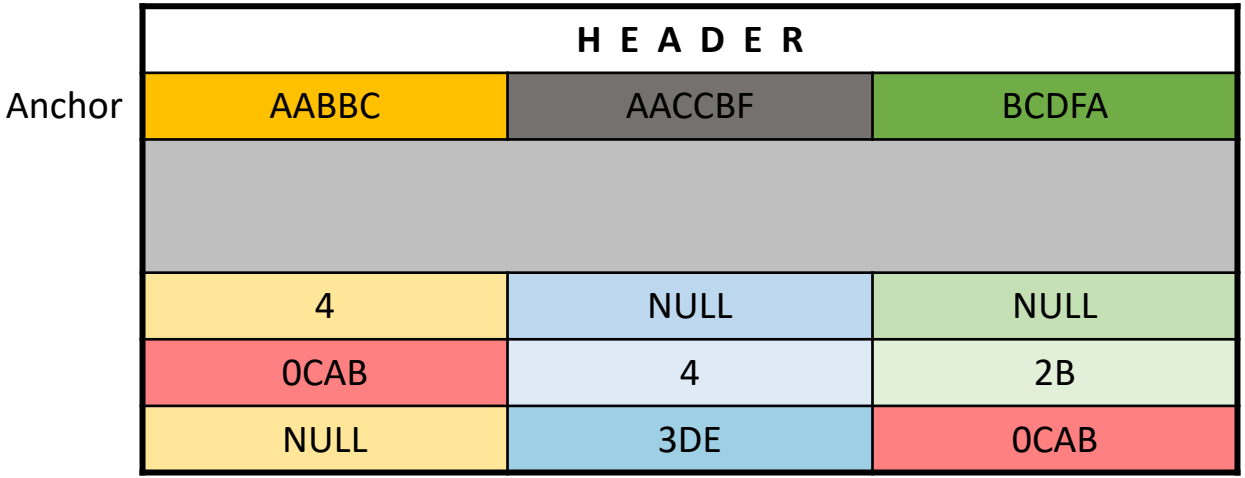
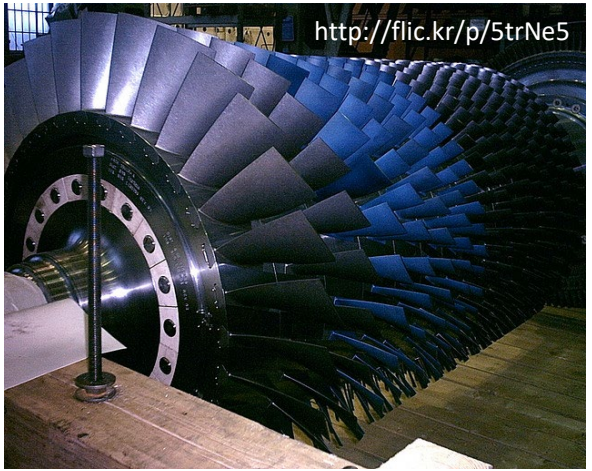


PAGE Compression (dictionary)

- De-duplicates common byte values over ALL columns on page
- Dictionary entries stored as a 0-based array
- Array is stored after anchor row in the CI structure
- Entries created only if a value repeats in 2 or more columns



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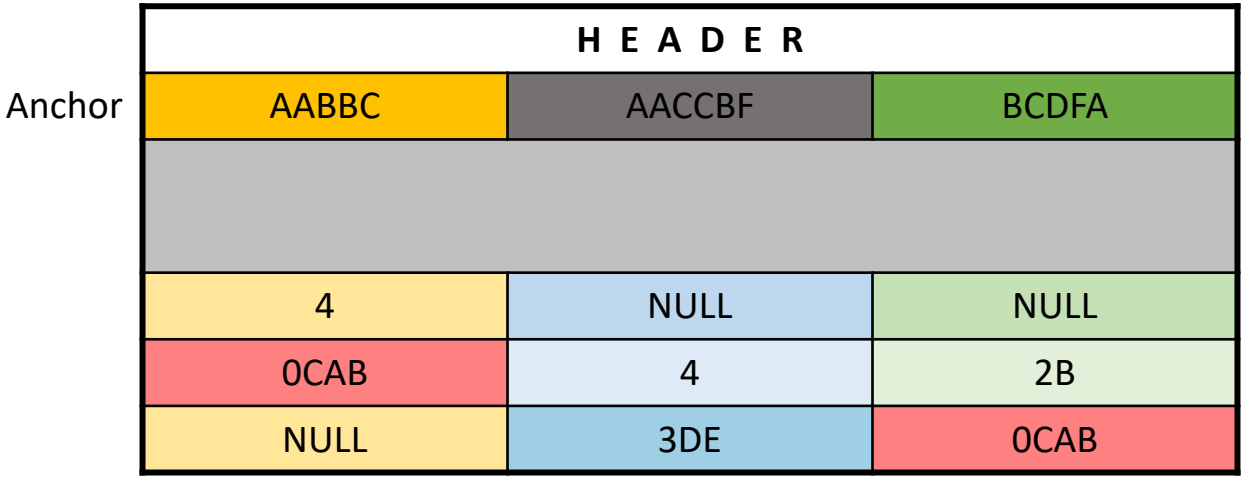

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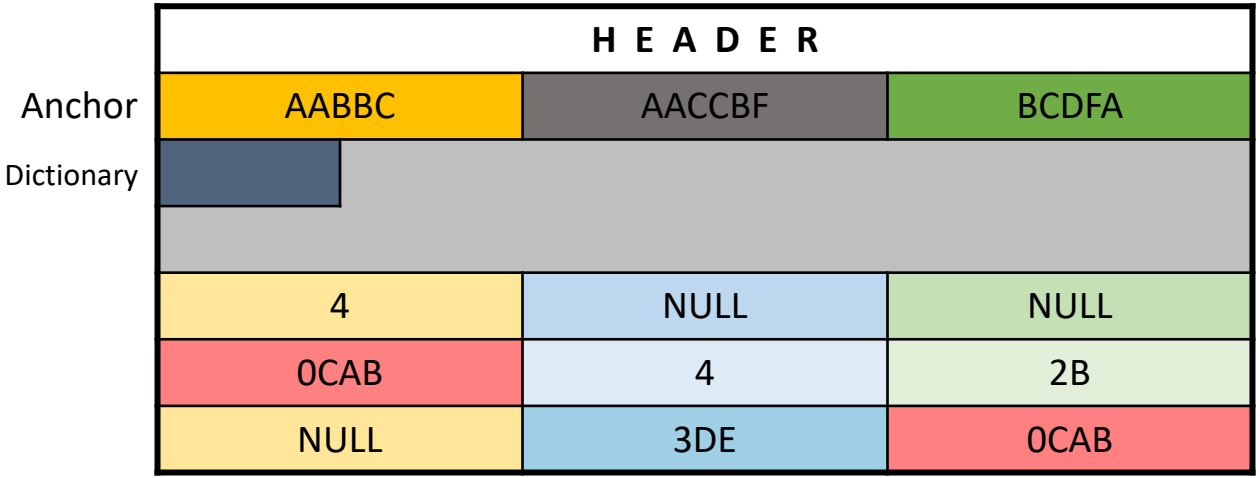

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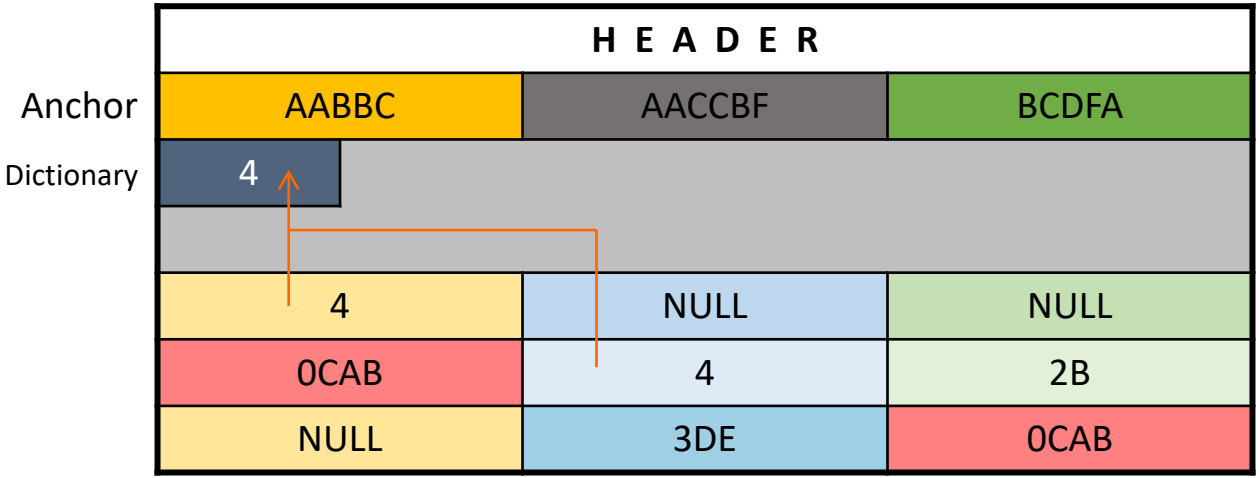

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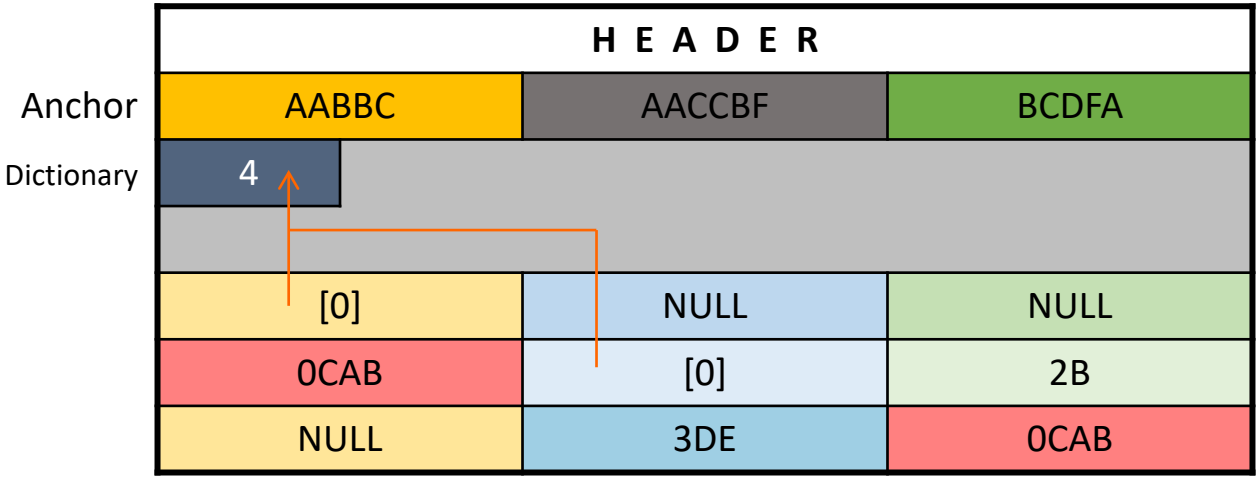

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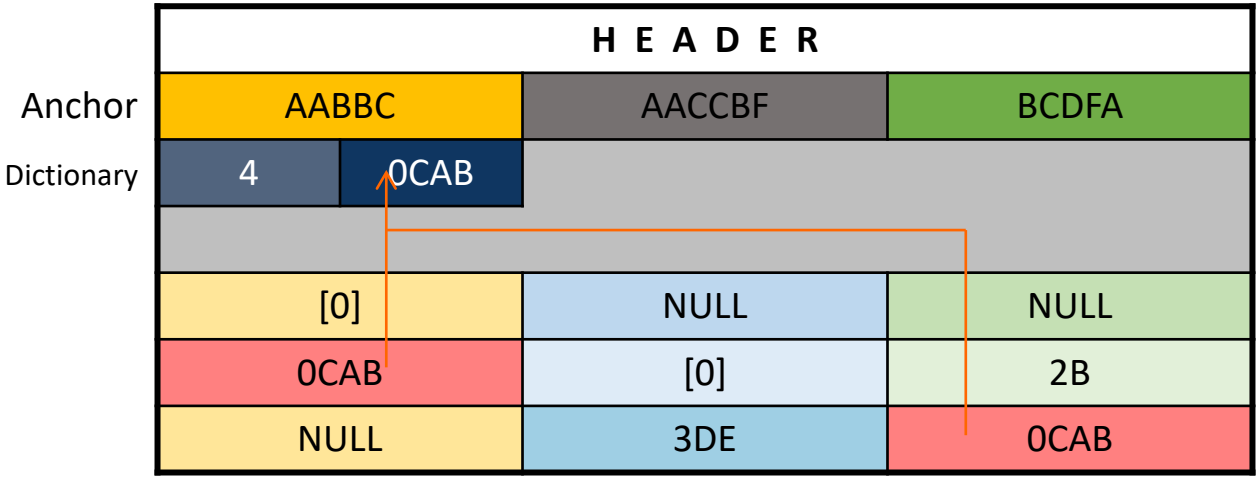
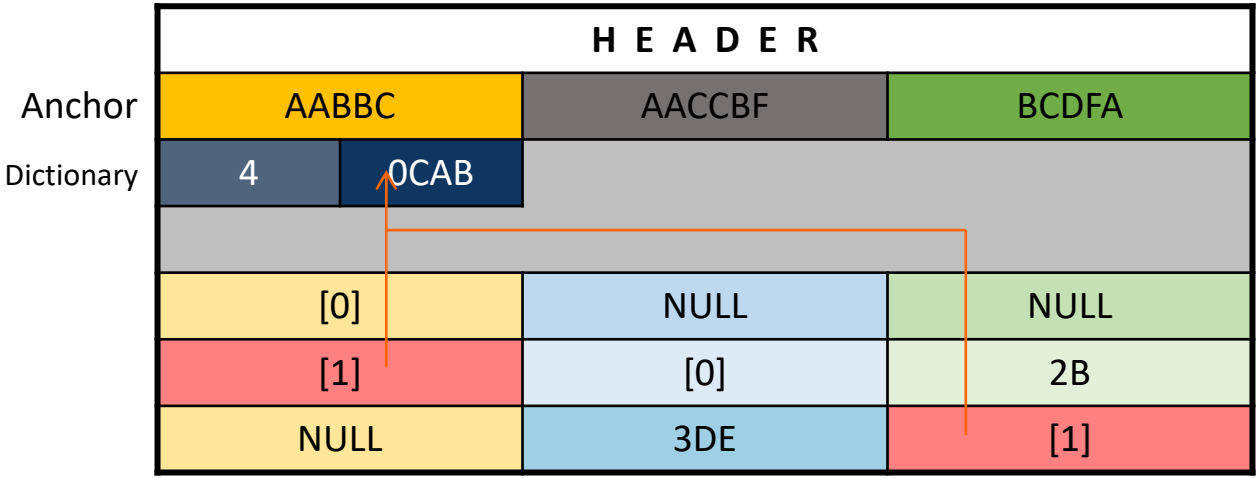


PAGE Compression (dictionary)



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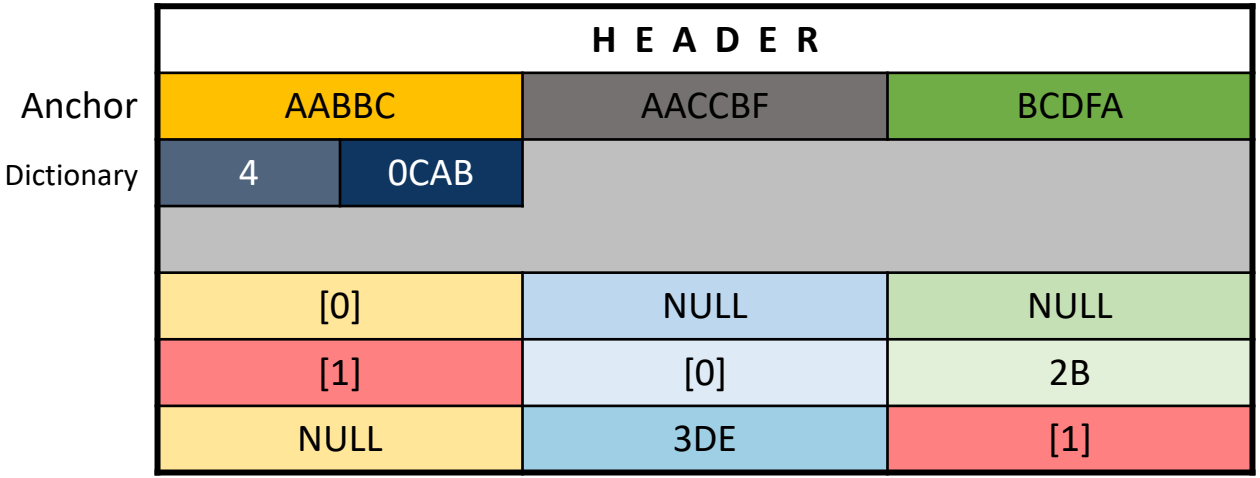
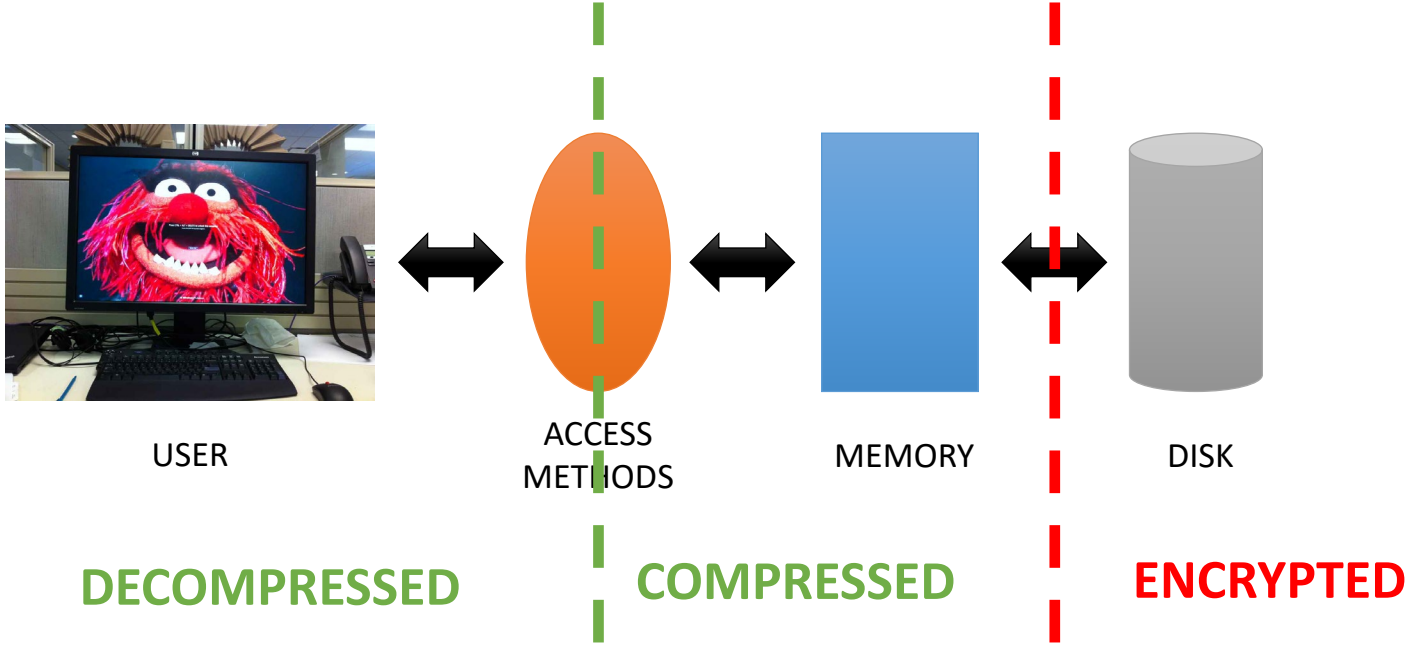


PAGE Compression

- CI Structure is rebuilt on an all-or-nothing basis
  - Updating 1 row probably won't trigger a rebuild
- Page modifications tracked in the CI Structure

- If PageModCount >25
- OR PageModCount / Rows on Page > 25%
- Then **TRIES** to rebuild CI Structure
- (Rebuild is only applied if rebuild creates enough space for 5 or 25% more rows)

Data Compression and TDE



Backup Compression is Different

- Data compression uses the described methods to shrink data in hopes of fitting more records on a page
- Backup compression uses a proprietary algorithm to compress the backup stream in hopes of making the backup file(s) smaller
- Both methods will use more CPU in hopes of reducing IO
- It is possible to use both methods together
  - Net effect of backup compression will be lower if data compression is already in place

What Can't Be Compressed?

- System Tables
- Anything not on a data or index page
  - Binary/LOB types (VARCHAR, TEXT, NTEXT, VARBINARY, IMAGE, SQL_VARIANT, UNIQUEIDENTIFIER, XML)
  - FILESTREAM
  - NVARCHAR(MAX) even when stored in-row

How Much Space Is Saved?

- It Depends!
- Proper datatyping reduces compression ratio
- Fewer repeating values also reduces compression ratio

- `sp_estimate_data_compression_savings`
  - Try before you compress!
  - Samples 5% of object in TempDB
  - Compresses & extrapolates

Data Compression Compatibility

- Introduced in SQL Server 2008
- WAS Enterprise Edition only until 2016 SP1
  - Would only restore on Enterprise Edition!
  - Didn't tell you this until the end of a restore!!
  - `sys.dm_db_persisted_sku_features`
- Can't be used with Sparse Columns

When To Use Row/Page Compression

- Most effective on tables with high number of scans
  - Savings are smaller from single lookups (reads or writes)
- Tables that have a high percentage of reads / READ_ONLY
- Data that is seldom accessed
- All the time?

What If My Storage Array Does Compression?

- Test it!
- Pros
  - Will probably compress better than Row/Page Compression
  - Not using database server CPUs to do this work
- Cons
  - Data won't be compressed in memory

Columnstore Compression

Columnstore over time

- Introduced in SQL Server 2012
  - Was read-only, nonclustered indexes only
  - Enterprise Edition only
- 2014
  - Added updateable clustered columnstore indexes
  - Still EE-only
- 2016
  - Updateable nonclustered columnstore indexes
  - Secondary b-tree indexes
  - Available in standard edition! (needs SP1)

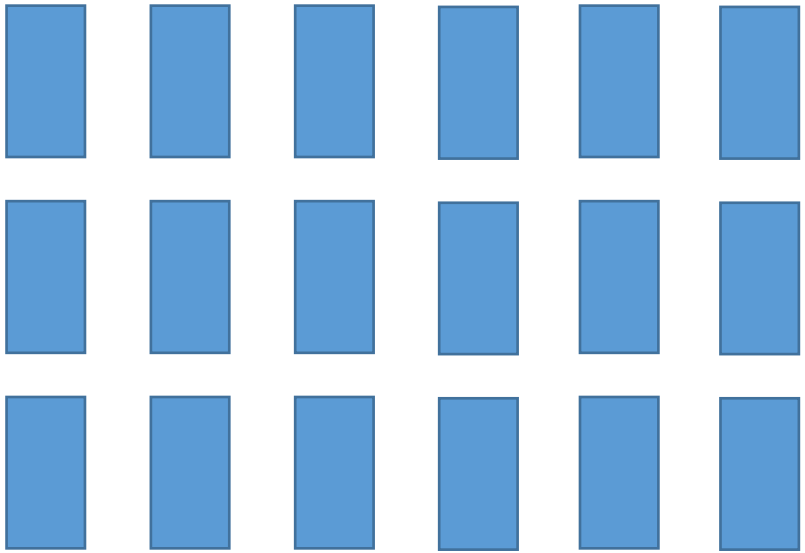
Columnstore over time

- 2017
  - Adaptive Query Processing added for tables w/ columnstore indexes
  - Can add computed columns to clustered columnstore indexes
- 2019
  - Online build/rebuild of clustered columnstore indexes

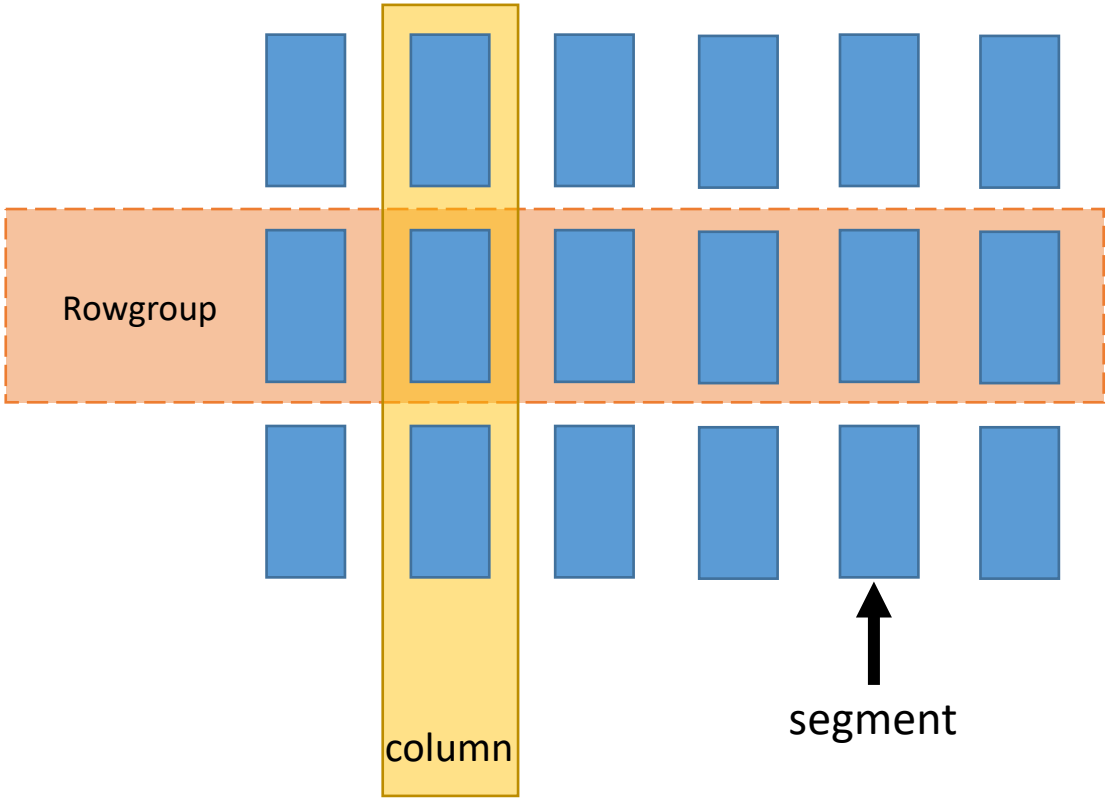
Columnstore

Relational Table (Rowstore)

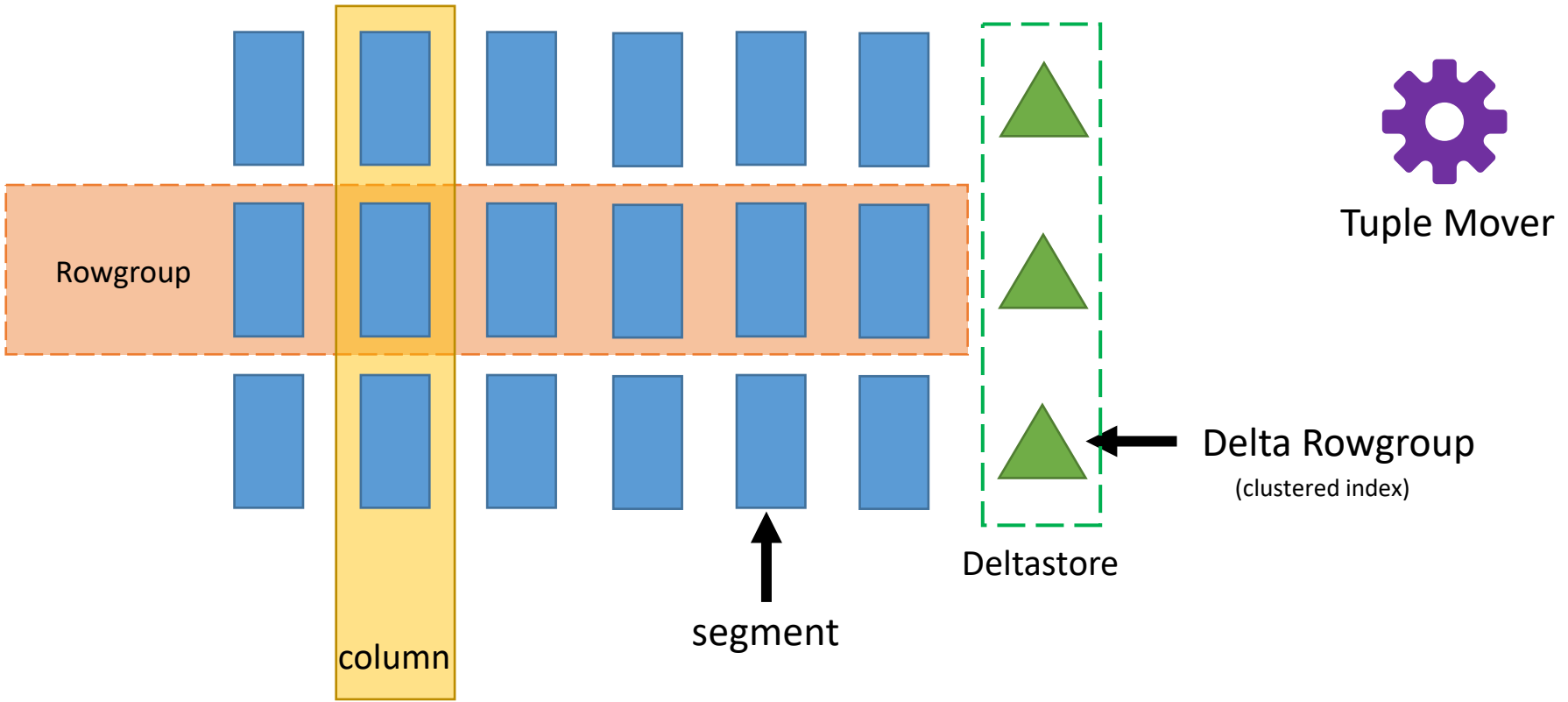
Columnstore



Columnstore



Columnstore



Columnstore Compression Algorithms

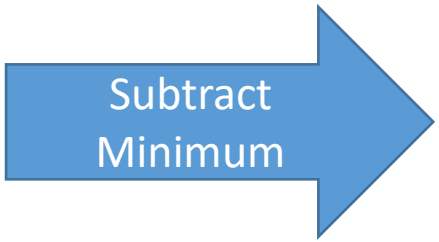
- Several compression algorithms possible
  - Decided upon by the engine based on profile of the data
  - You get no control over this

Value-Based Encoding (aka “Value Scale”)

- Create a mathematical relationship between value & stored value

Value
1105
1109
1122
1113
1107

Min: 1105
Max 1122
11 bits needed



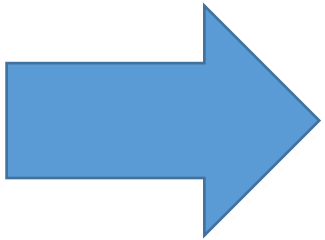
Value
0
4
17
8
2

Min: 0
Max 17
5 bits needed
“base” = 1105

Bit Array

- Stores a bit column for each distinct value found

Blood Group
A
O
AB
O
A
B
A

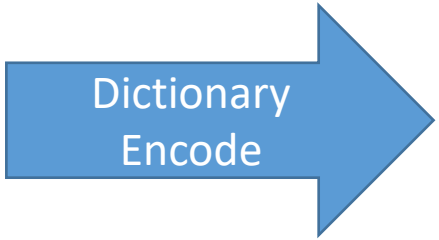


A	B	O	AB
1	0	0	0
0	0	1	0
0	0	0	1
0	0	1	0
1	0	0	0
0	1	0	0
1	0	0	0

Dictionary Encoding

- Build a dictionary of distinct values & replace data with them

Vehicle Make
Chevy
Chevy
Ford
Audi
Tesla
Ford
Chevy



Make ID
0
0
1
2
3
1
0

Dictionary

ID	Make
0	Chevy
1	Ford
2	Audi
3	Tesla

Huffman Coding

- An optimal prefix algorithm
- More-common values are represented using fewer bits

Dictionary

ID	Make	Bits Req'd
0	Chevy	1
1	Ford	1
2	Audi	2
3	Tesla	2
…		
95	Bugatti	7

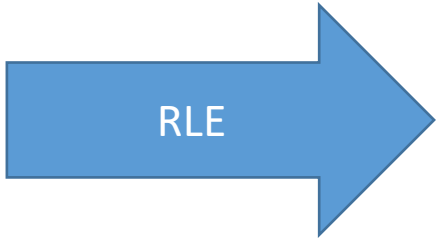
Run Length Encoding (RLE)

- Avoids repetition by grouping same values together

Color
Red
Red
…
Blue
Blue
Blue
…

105x

92x

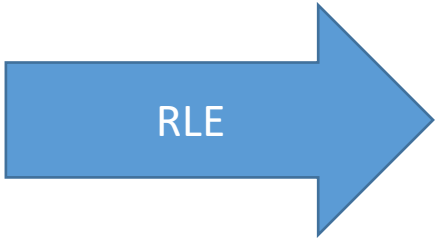


Color	Count
Red	105
Blue	92

Run Length Encoding (RLE)

- Can be less efficient depending on ordering

Color
Red
Red
Blue
Red
Blue
Blue
Blue



Color	Count
Red	2
Blue	1
Red	1
Blue	3

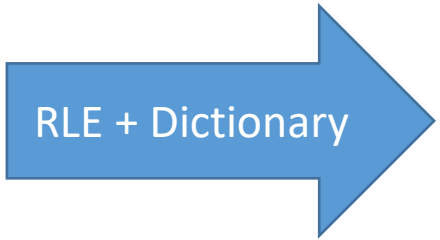
Run Length Encoding (RLE)

- Can combine with dictionary

Color
Red
Red
Blue
Red
Blue
Blue
Blue

Dictionary

ID	Color
0	Red
1	Blue



Color ID	Count
0	2
1	1
0	1
1	3

Columnstore Archival Compression

- The one option you do have for columnstore compression
  - Further compresses the columnstore index to save space
  - Requires more time for storage & retrieval
- Adds another layer of compression
  - Modified LZ77?

When Should Columnstore Be Used?

- Queries that scan large amounts of data
  - Especially on large tables
- Datasets with highly-repetitive values
- Data Warehousing Workloads
  - Fact Tables
  - Large Dimension Tables
- Real-time analysis on OLTP workloads

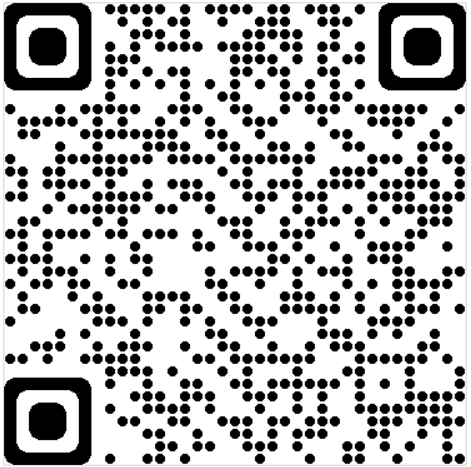
When Should Columnstore Be Avoided?

- “Small tables” (under 1M rows)
  - Won’t benefit from compression or be stored as segments
- Columns containing highly-unique strings
- Queries that usually return all rows in a table
  - Data won’t be returned any faster by a columnstore index
- Frequently updated tables

Resources

- Jonathan Kehayias shows how to use XE to track compression operations: http://www.sqlskills.com/blogs/jonathan/post/An-XEvent-a-Day-(28-of-31)-e28093-Tracking-Page-Compression-Operations.aspx
- Sanjay Mishra whitepaper on Data Compression strategy & best practices: http://msdn.microsoft.com/en-us/library/dd894051(SQL.100).aspx
- MCM Readiness video on SQL Server data compression: http://technet.microsoft.com/en-us/sqlserver/gg313758.aspx
- Niko Neugebauer on columnstore indexes: http://www.nikoport.com/columnstore/
- Materials from this session, more resources, etc: https://www.bobpusateri.com/r/Compression

Questions? THANK YOU FOR ATTENDING!



Evaluations!

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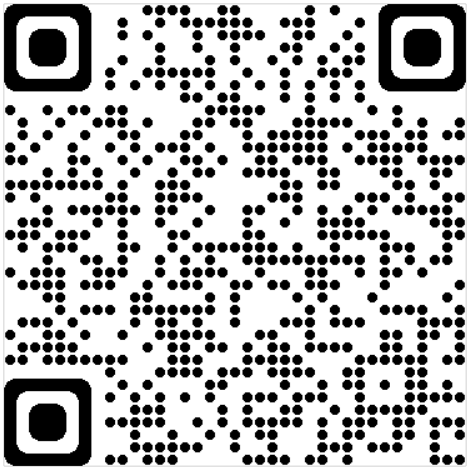

Session Materials!

www.bobpusateri.com/r/Compression