

# Managing PMU Datasets with Bitmap Indexes

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# Terminology 1

- Bitmap: A binary representation of a dataset allowing for efficient retrieval of data.
- PMU: Next generation sensor of voltage and phase for the grid.

# The Benefits of Bitmaps for Managing Synchronophasor Signals

- Compressed bitmap
- Queries can be performed in memory
- Reduce disk access
- No disk access required to obtain some results

# Terminology 2

- A Word

0001010101010101010101100101010001

- Fills and Literals
- Runs and Dirty Bits
- Candidacy Check

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- A Word
- Fills and Literals
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110001

00010101011101010101100101010001

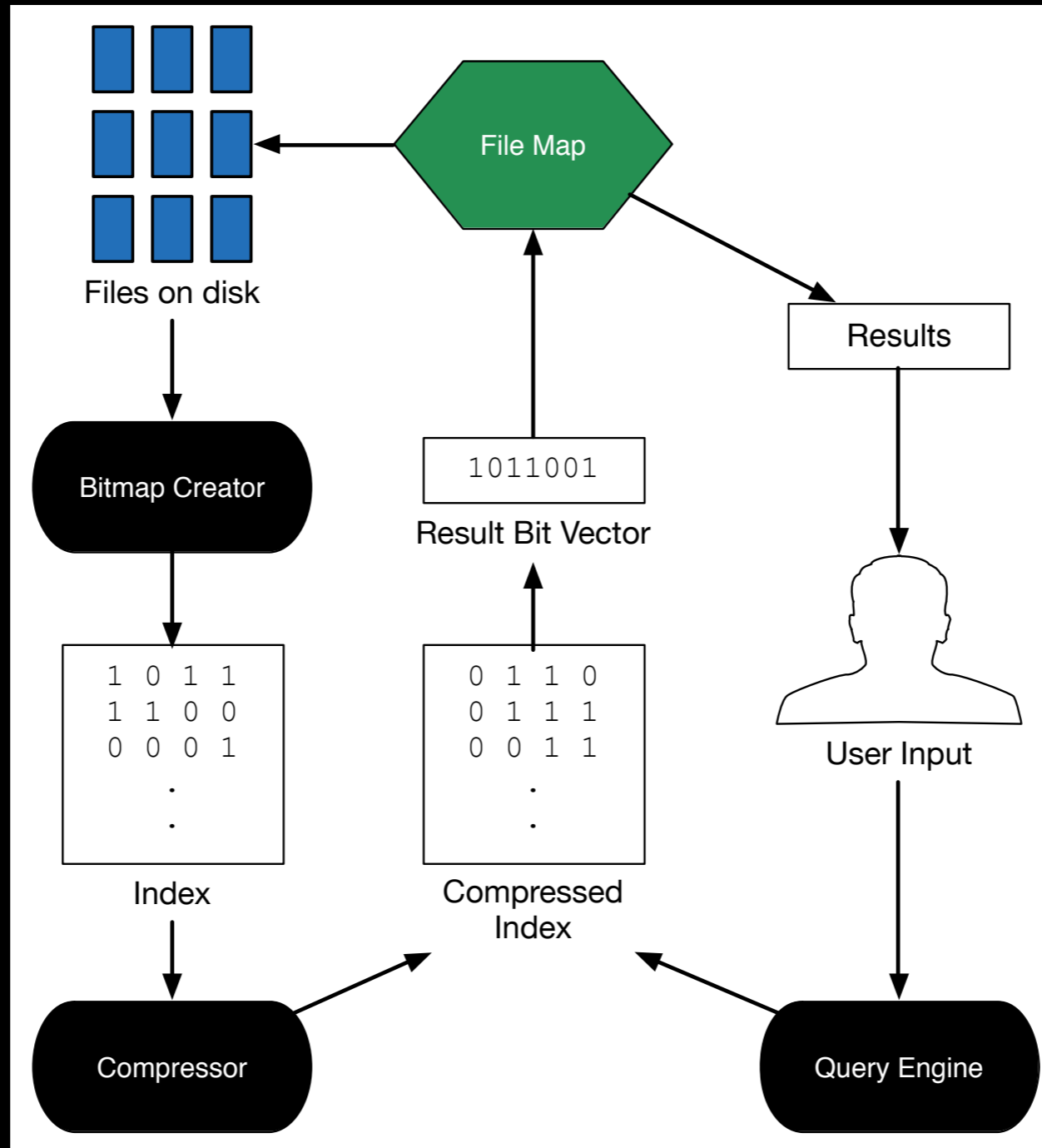
# Terminology 2

- A Word
- Fills and Literals
- Runs and Dirty Bits
- Candidacy Check

0000000000...

0000010000...

# The System



# Bitmap Creation

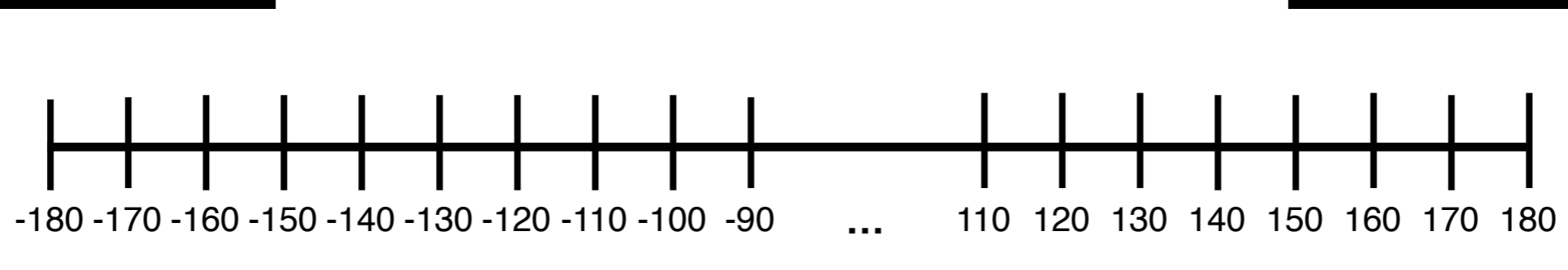
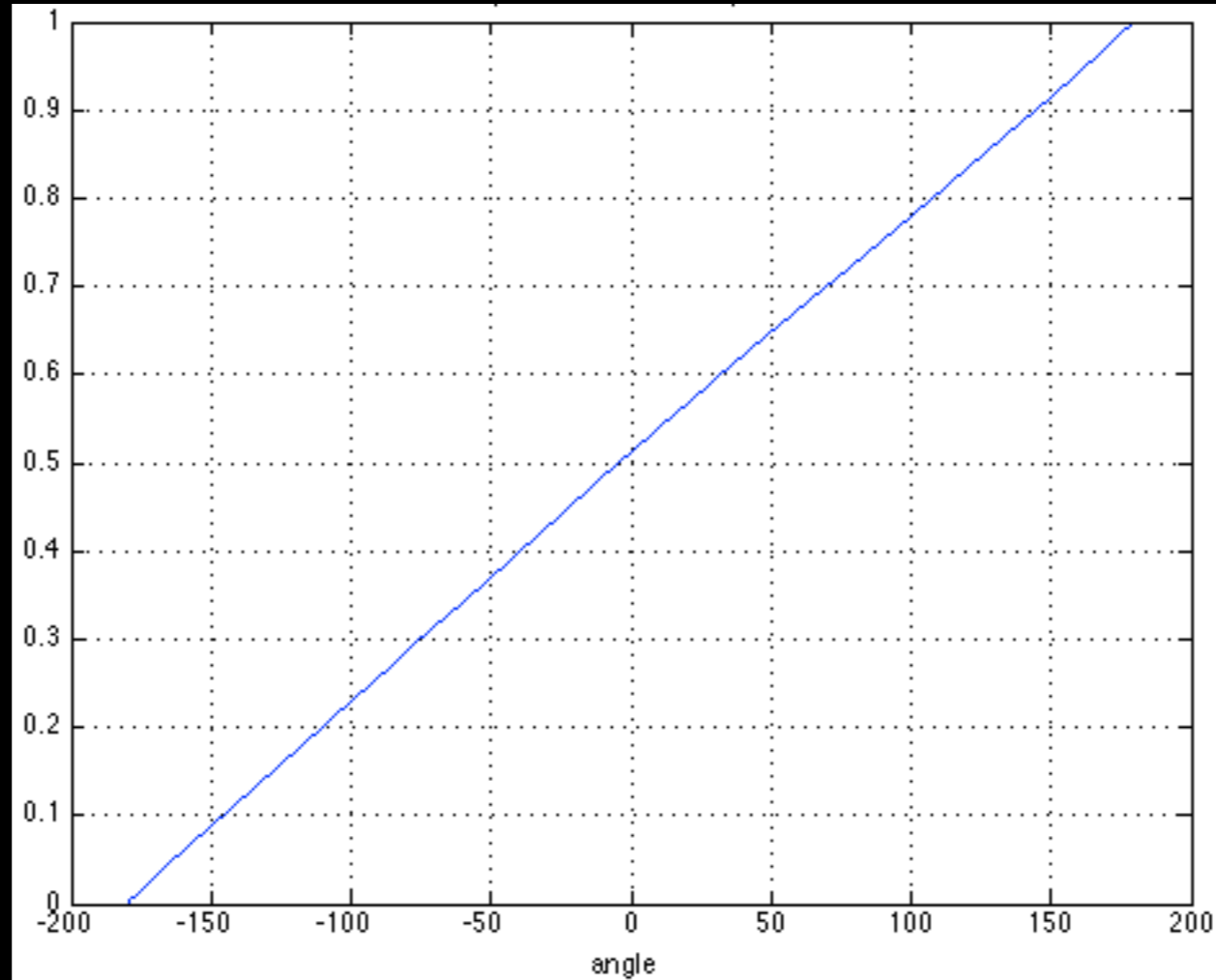
Time	PMU1		PMU2	
[sec]	Magnitude [kv]	Phase [deg.]	Magnitude [kv]	Phase [deg.]
0.0	325	-140	325	-120
0.0167	326	-120	325	-130
0.0333	327	-140	327	-140
0.05	328	-140	325	-130
0.0667	327	-140	326	-130



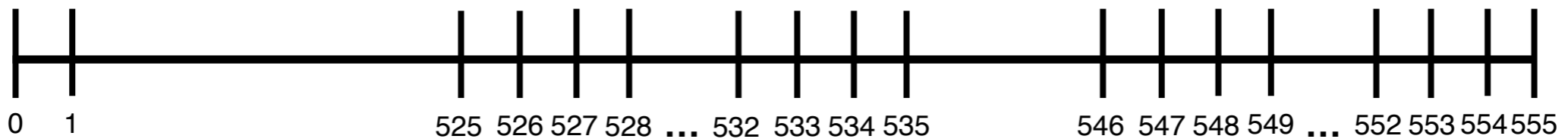
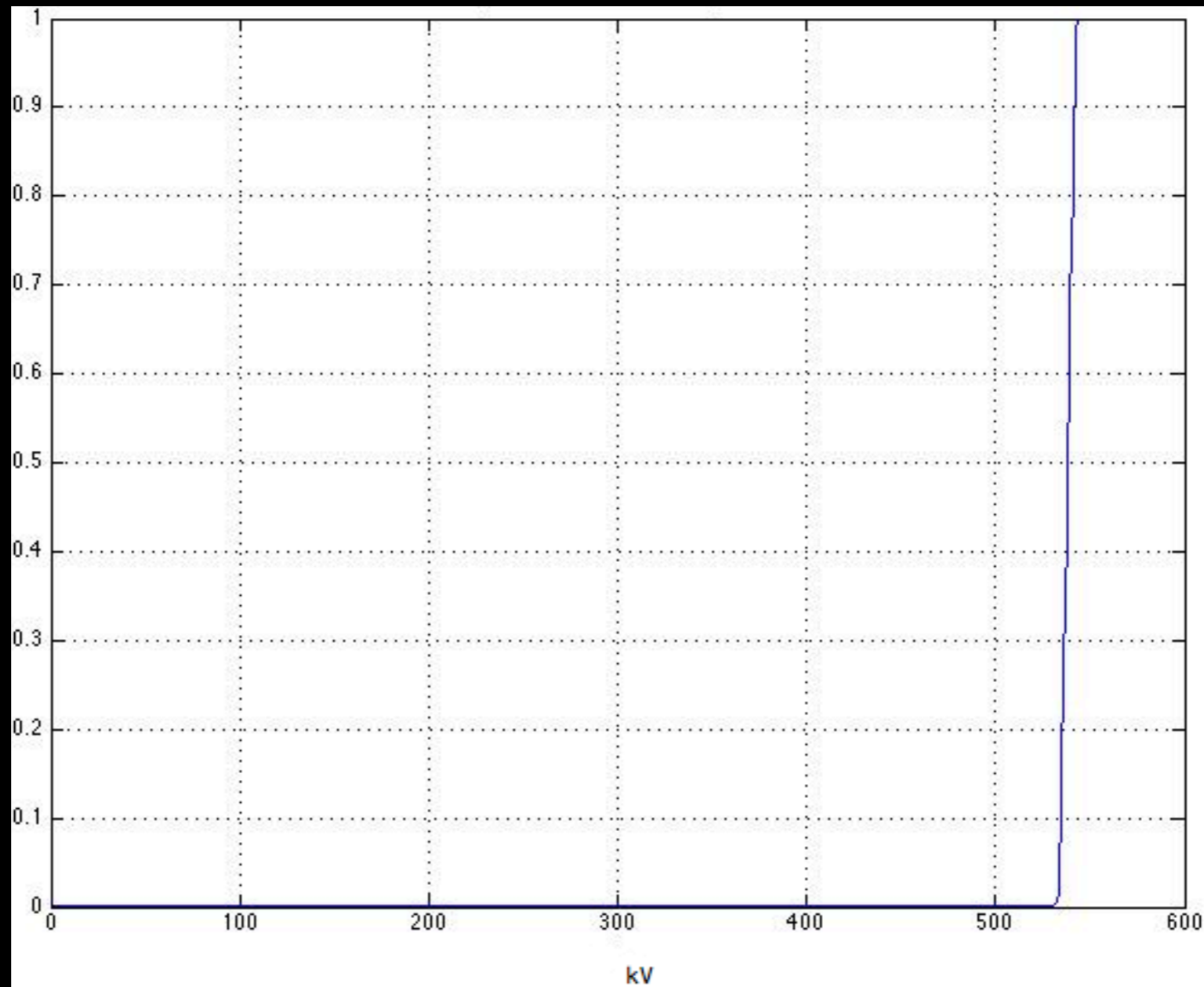
# Bitmap Creation

Second	Milliseconds			Magnitude PMU1				Phase PMU1		
[0-1)	[0-40)	[40-60)	[60-80)	[325-326)	[326-327)	[327-328)	[328-329)	[-120 - -130)	[-130 - -140)	[-140 - -150)
1	1	0	0	1	0	0	0	0	0	1
1	1	0	0	0	1	0	0	1	0	0
1	1	0	0	0	0	1	0	0	0	1
1	0	1	0	0	0	0	1	0	0	1
1	0	0	1	0	0	1	0	0	0	1

# Characterization of Data



# Characterization of Data



# Binning

- Year: 11
- Month: 12
- Day: 31
- Hour: 24
- Minute: 60
- Second: 60
- Millisecond: 10
- Phase (36 for each PMU): 40 x 36
- Magnitude (23 for each PMU): 40 x 23
- Delta Phase (180 for each PMU): 40 x 180

# Bitmap Compression

## Uncompressed Bit Vector (1155 bits)

1011110111111111111111111111111100000001 111111111111111...1

The diagram shows a long bit vector. The first 31 bits are grouped with a bracket labeled '31'. The remaining bits are grouped with a bracket labeled '15x31', indicating 15 groups of 31 bits each. The bit vector is: 1011110111111111111111111111111100000001 111111111111111...1

## WAH Compressed Bit Vector (32 bits)

0101111011111111111111111111111100000001 11000000000000000000000000000000101111

The diagram shows a compressed bit vector of 32 bits, split into two segments. The first segment is '0101111011111111111111111111111100000001' and the second segment is '11000000000000000000000000000000101111'. The segments are enclosed in rounded rectangular boxes.

# Queries

**Tuples where Magnitude is 325 and occurs in the month  
of July**

Mag:01010101..01 1000..0111010 011111111..11

Mon:01111111..11 010101010..01 1000..0111001 011111111..11

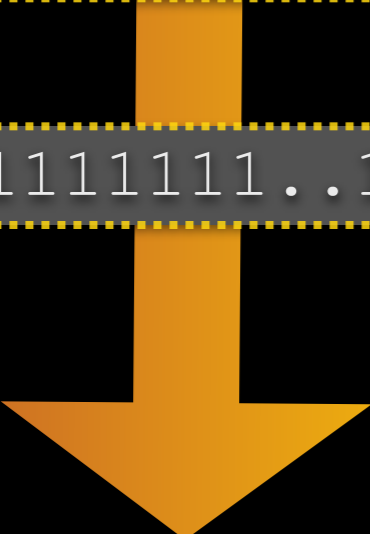
# Queries

## Magnitude&Month

Mag: 01010101..01 1000..0111010 011111111..11

Mon: 01111111..11 010101010..01 1000..0111001 011111111..11

res: 01010101..01



# Queries

## Magnitude&Month

26 Runs = 806 Bits





# Queries

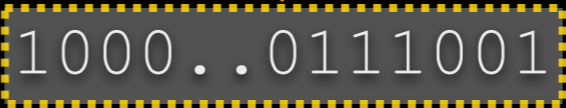
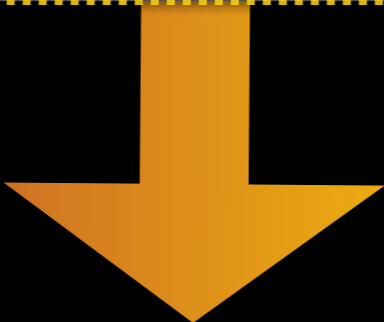
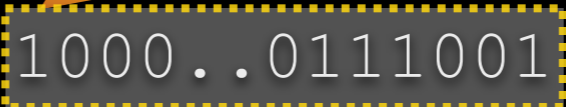
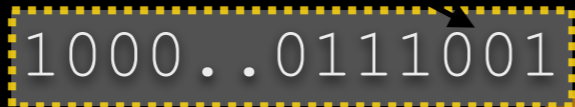
## Magnitude&Month

25 Runs = 775 Bits

Mag: 01010101..01 1000..0111001 011111111..11

Mon: 01111111..11 010101010..01 1000..0111001 011111111..11

res: 01010101..01 000000000..00 1000..0111001



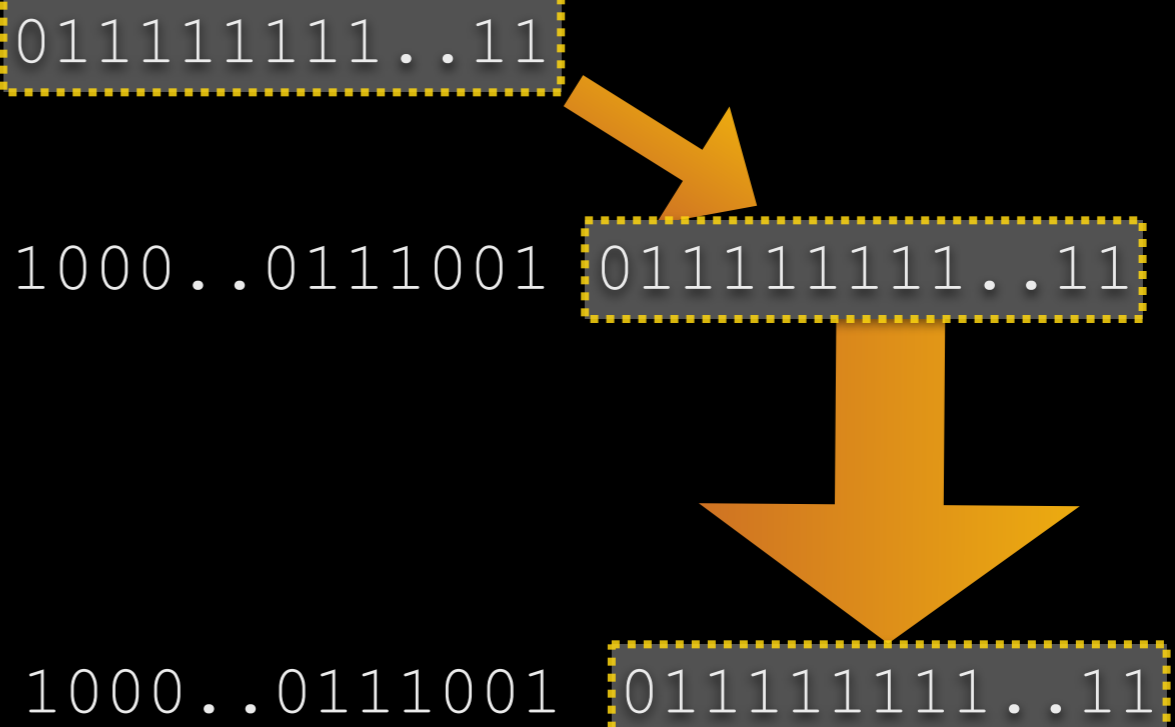
# Queries

## Magnitude&Month

Mag:01010101..01 1000..0111010 011111111..11

Mon:01111111..11 010101010..01 1000..0111001 011111111..11

res:01010101..01 000000000..00 1000..0111001 011111111..11



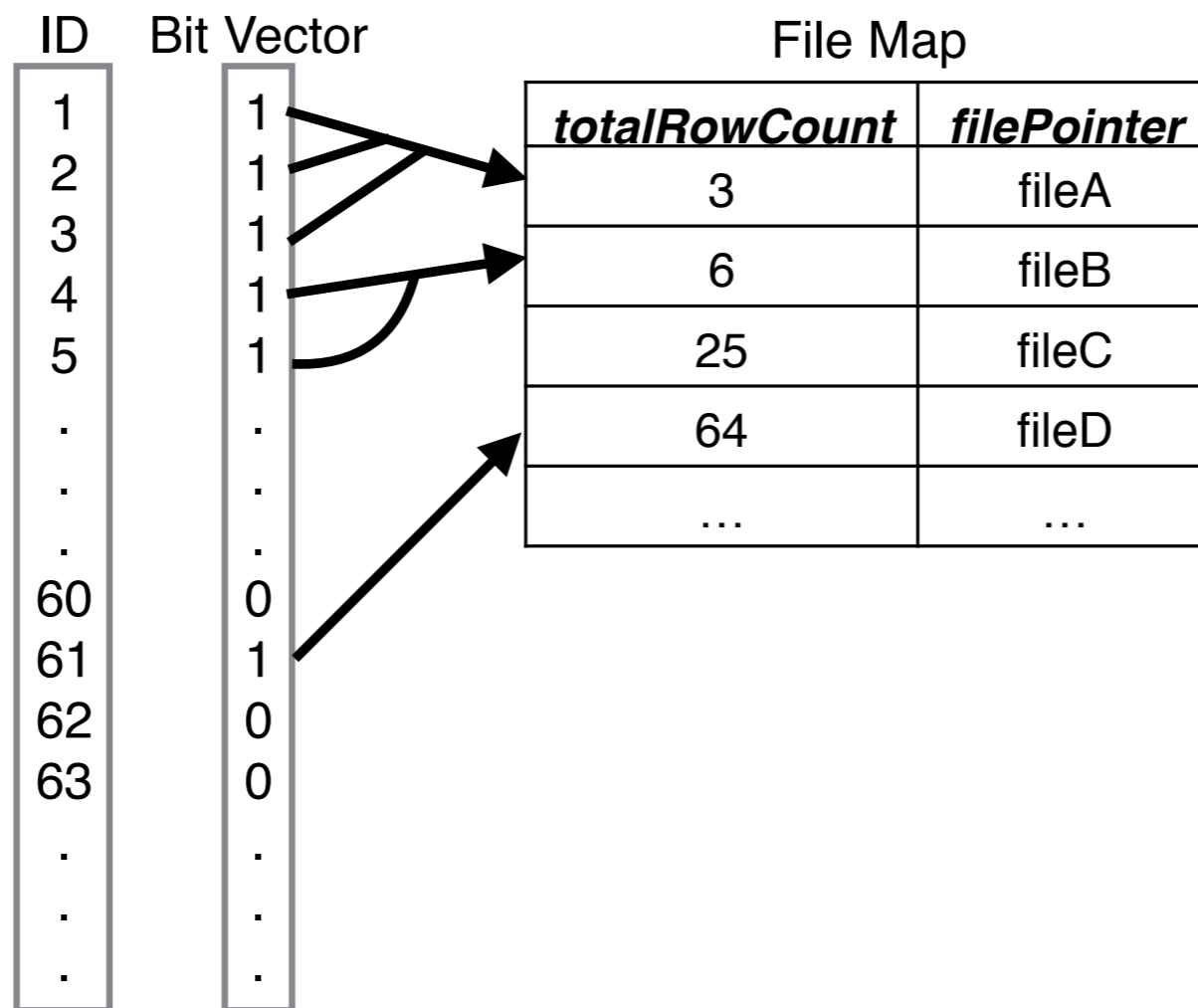
# Queries

Mag:01010101..01 1000..0111010 011111111..11

Mon:01111111..11 010101010..01 1000..0111001 011111111..11

res:01010101..01 000000000..00 1000..0111001 011111111..11

# FileMap



# Results

<b>ID</b>	<b>Selection Criteria</b>	<b>Linear (sec)</b>	<b>Scan</b>	<b>Bitmap (sec)</b>	<b>Tuples Retrieved</b>
1	Find all tuples where PMU1 has a magnitude Voltage Magnitude of 533.	25.859666		0.379387	160
2	Find all tuples that happened on exactly June 24, 2013 at 21:05 hours.	25.350993		0.854952	7204
3	Find all tuples that happened on exactly June 24, 2013 at 21:06 hours.	28.001001		0.922941	7204
4	Find all tuples that happened on exactly June 24, 2013 at 21:07 hours.	26.133607		0.785588	7204
5	Find all tuples that happened on exactly June 24, 2013 at 21:06 hours with PMU having a Voltage Magnitude of 533.	28.019449		0.001772	0
6	Find all tuples in 2012.	26.720291		0.0000601	0

Thank You

Questions?