

## 1 Pre-Check

This section is designed as a conceptual check for you to determine if you conceptually understand and have any misconceptions about this topic. Please answer true/false to the following questions, and include an explanation:

For more information on higher level vs. lower level, visit [https://en.wikipedia.org/wiki/High\\_and\\_low-level](https://en.wikipedia.org/wiki/High_and_low-level)

The higher the PUE the more efficient the datacenter is.

Hamming codes can detect any type of data corruption.

All RAID levels improve reliability.

## 2 Hamming ECC

Recall the basic structure of a Hamming code. We start out with some bitstring, and then add parity bits at the indices that are powers of two (1, 2, 8, etc.). We don't assign values to these parity bits yet. **Note that the indexing convention used for Hamming ECC is different from what you are familiar with.** In particular, the 1 index represents the MSB, and we index from left-to-right. The  $i$ th parity bit  $P\{i\}$  covers the bits in the new bitstring where the *index* of the bit under the aforementioned convention,  $j$ , has a 1 at the same position as  $i$  when represented as binary. For instance, 4 is  $0b100$  in binary. The integers  $j$  that have a 1 in the same position when represented in binary are 4, 5, 6, 7, 12, 13, etc. Therefore,  $P4$  covers the bits at indices 4, 5, 6, 7, 12, 13, etc. A visual representation of this is:

Bit position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Encoded data bits	p1	p2	d1	p4	d2	d3	d4	p8	d5	d6	d7	d8	d9	d10	d11	p16	d12	d13	d14	d15	
Parity bit coverage	p1	X		X		X		X		X		X		X		X		X		X	
	p2		X	X			X	X			X	X			X	X			X	X	
	p4				X	X	X	X					X	X	X	X					X
	p8								X	X	X	X	X	X	X	X					
	p16																X	X	X	X	X

Source: [https://en.wikipedia.org/wiki/Hamming\\_code](https://en.wikipedia.org/wiki/Hamming_code)

2.1 How many bits do we need to add to  $0011_2$  to allow single error correction?

- 2.2 Which locations in  $0011_2$  would parity bits be included?
- 2.3 Which bits does each parity bit cover in  $0011_2$ ?
- 2.4 Write the completed coded representation for  $0011_2$  to enable single error correction. Assume that we set the parity bits so that the bits they cover have even parity.
- 2.5 How can we enable an additional double error detection on top of this?
- 2.6 Find the original bits given the following SEC Hamming Code:  $0110111_2$ . Again, assume that the parity bits are set so that the bits they cover have even parity.
- 2.7 Find the original bits given the following SEC Hamming Code:  $1001000_2$

### 3 RAID

- 3.1 Fill out the following table:

	<b>Configuration</b>	<b>Pro/Good for</b>	<b>Con/Bad for</b>
RAID 0			
RAID 1			
RAID 2			
RAID 3			
RAID 4			

RAID 5			
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## 4 Warehouse-Scale Computing

Sources speculate Google has over 1 million servers. Assume each of the 1 million servers draw an average of 200W, the PUE is 1.5, and that Google pays an average of 6 cents per kilowatt-hour for datacenter electricity.

- 4.1 Estimate Google's annual power bill for its datacenters.
- 4.2 Google reduced the PUE of a 50,000-machine datacenter from 1.5 to 1.25 without decreasing the power supplied to the servers. What's the cost savings per year?