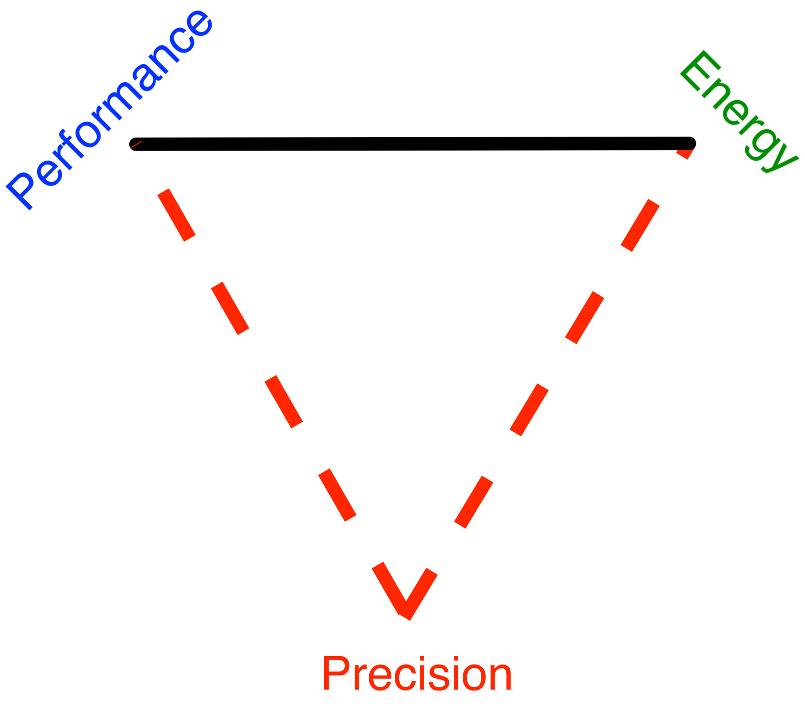
Probable Cause

The Deanonymizing Effects of Approximate DRAM

Amir Rahmati, Matthew Hicks, Dan Holcomb, Kevin Fu

Approximate Computing



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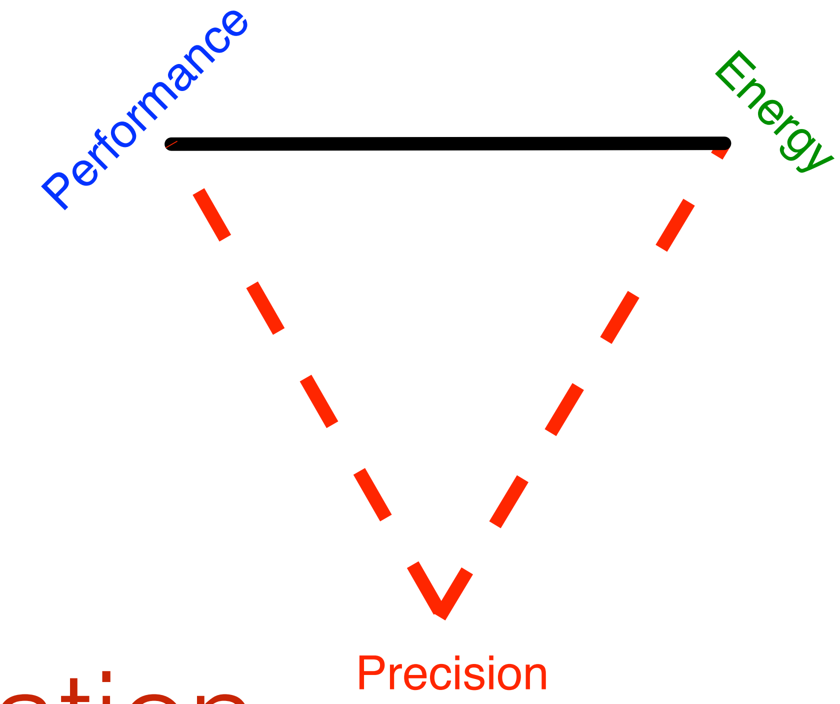

Precise computation
is **not** required
in many applications:

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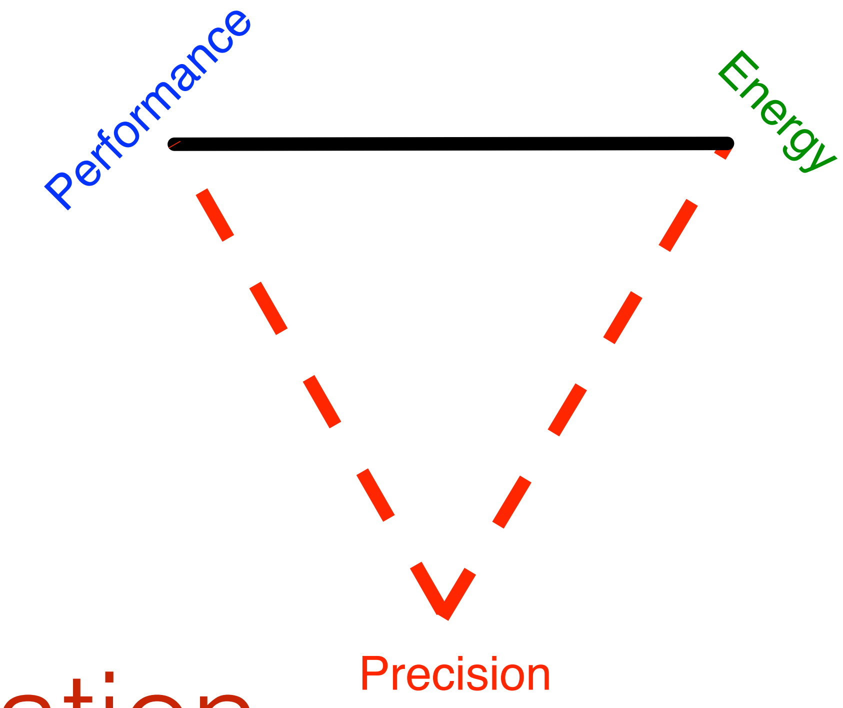

Precise computation
is **not** required
in many applications: Machine learning, sensory data, information retrieval, physical simulation, computer vision…

Approximate Computing

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Programming Language

UncertainT (ASPLOS’14)
Enerj (PLDI’11)

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Flikker (ASPLOS’11)
Approximate storage in
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Truffle (ASPLOS’12)
Relax (ISCA’10)
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How does Approximate Computing affect the end-user?

Green (PLDI'10)

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Architecture

Privacy Implications of Approximate DRAM

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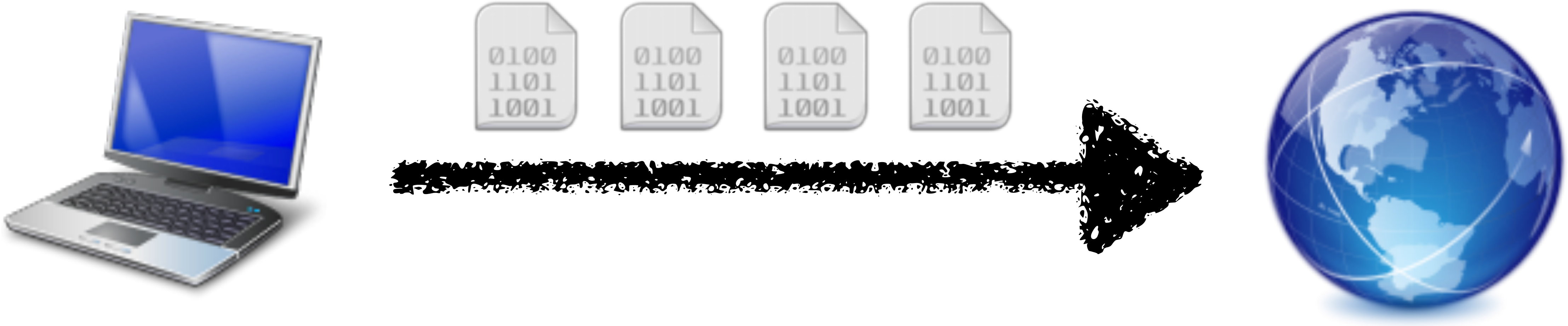
Identify the origin of data by looking at the error pattern

Overview



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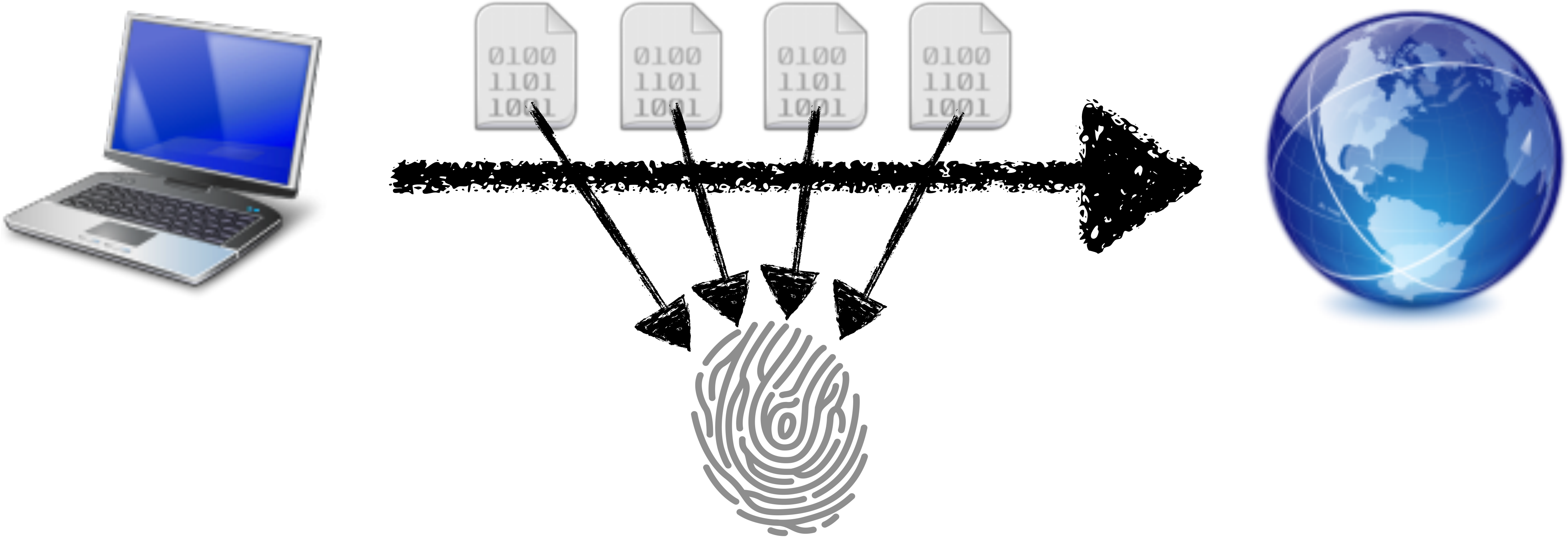

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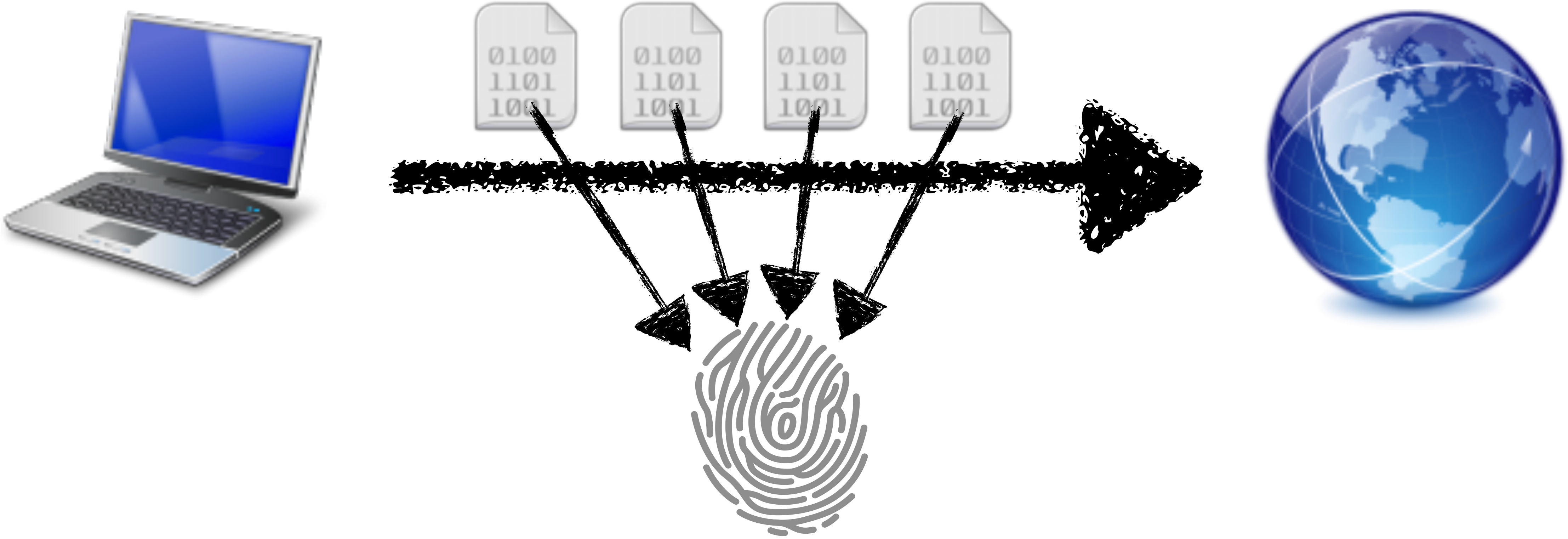

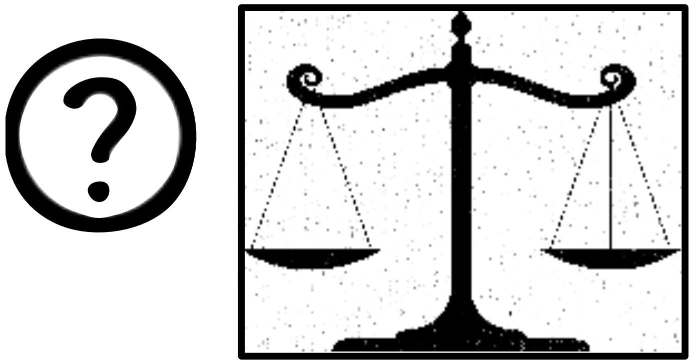

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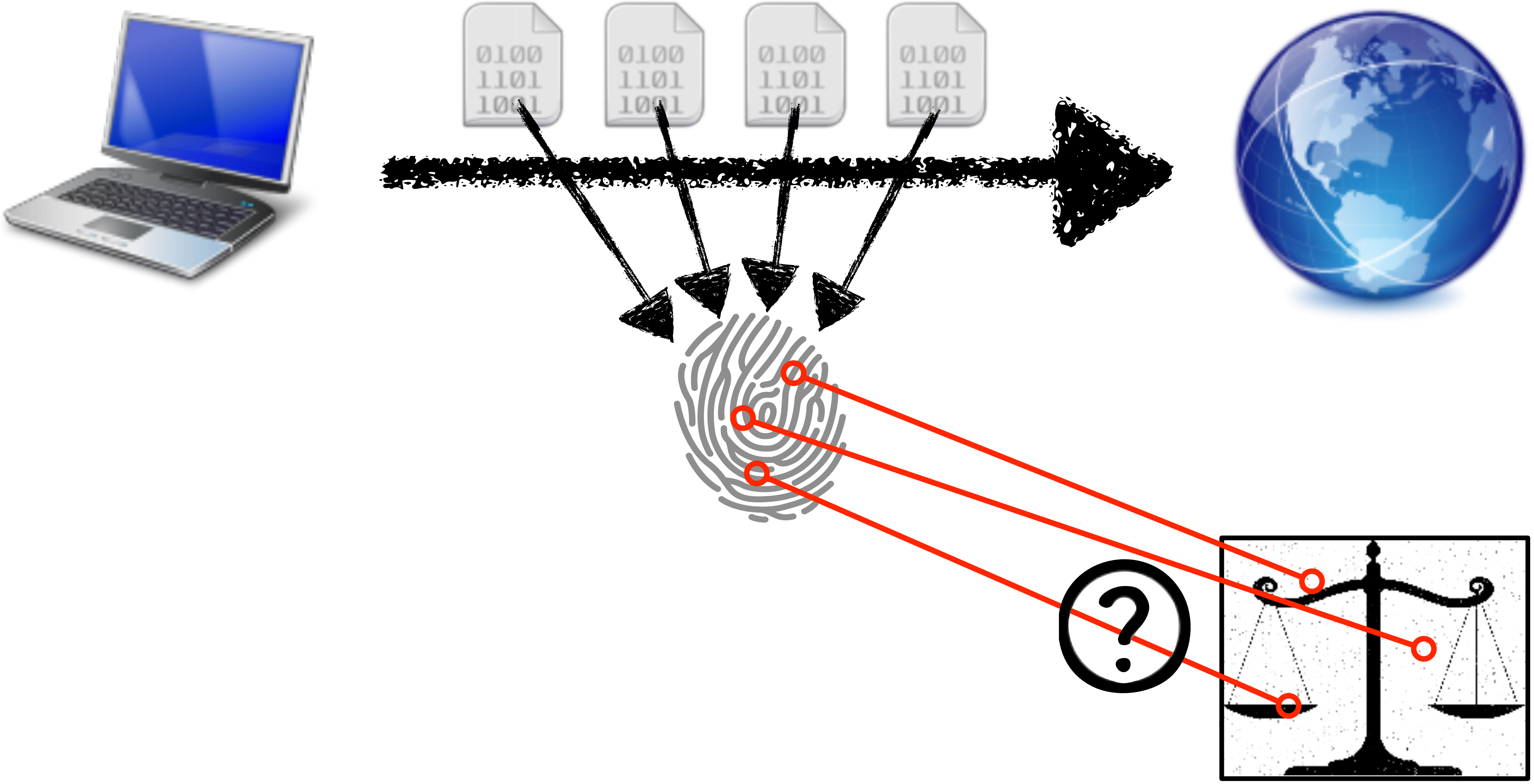

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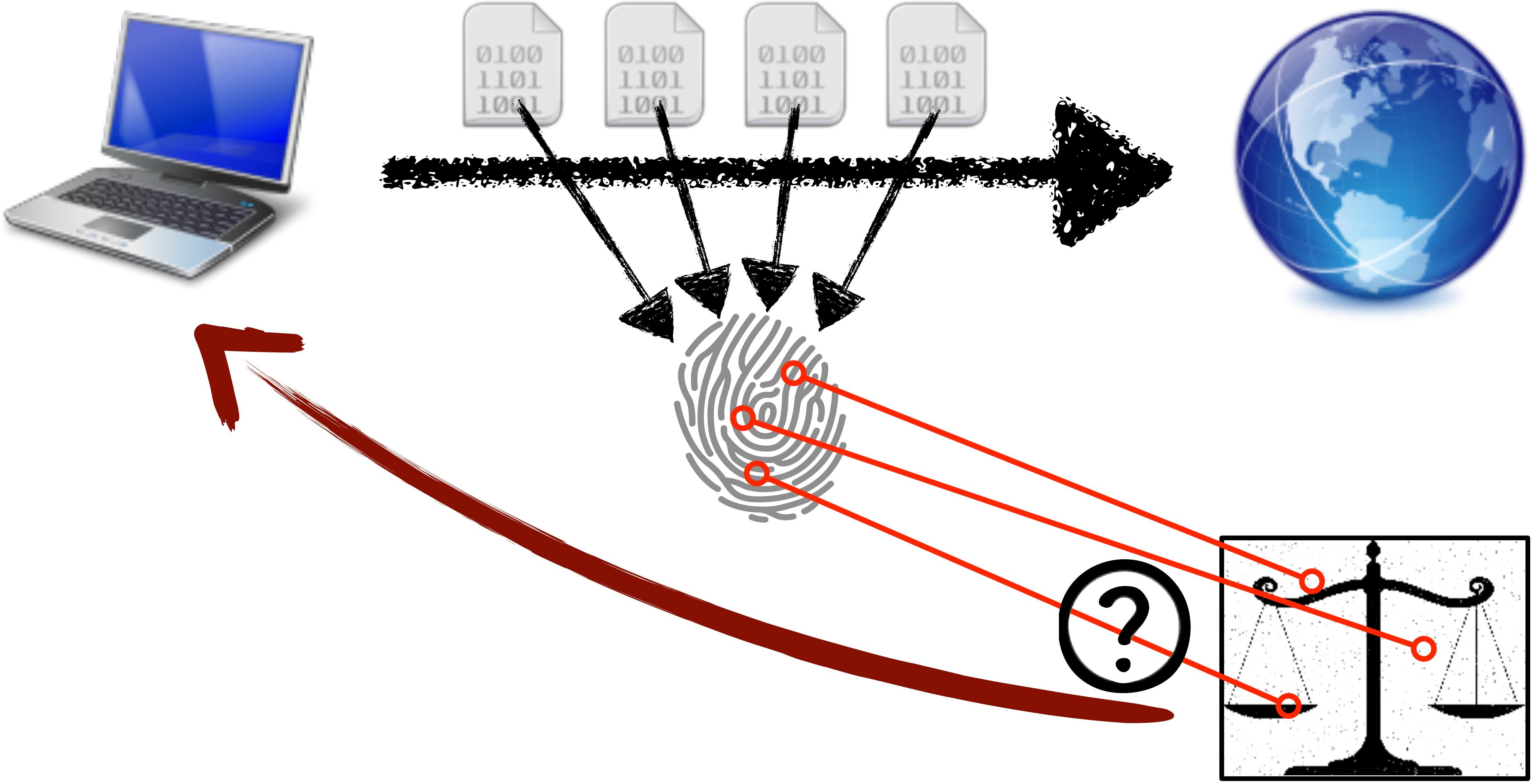
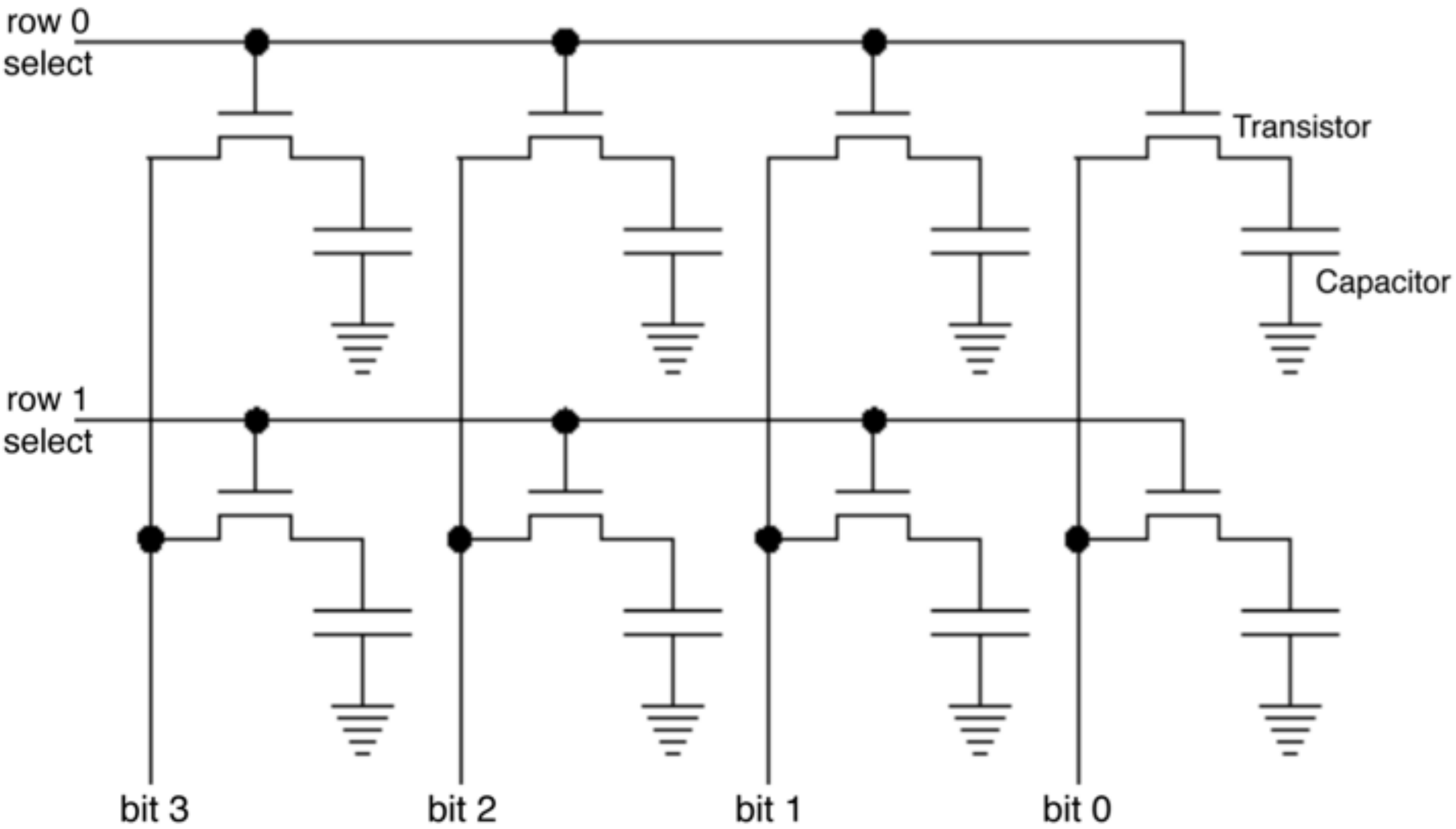


Background on DRAM



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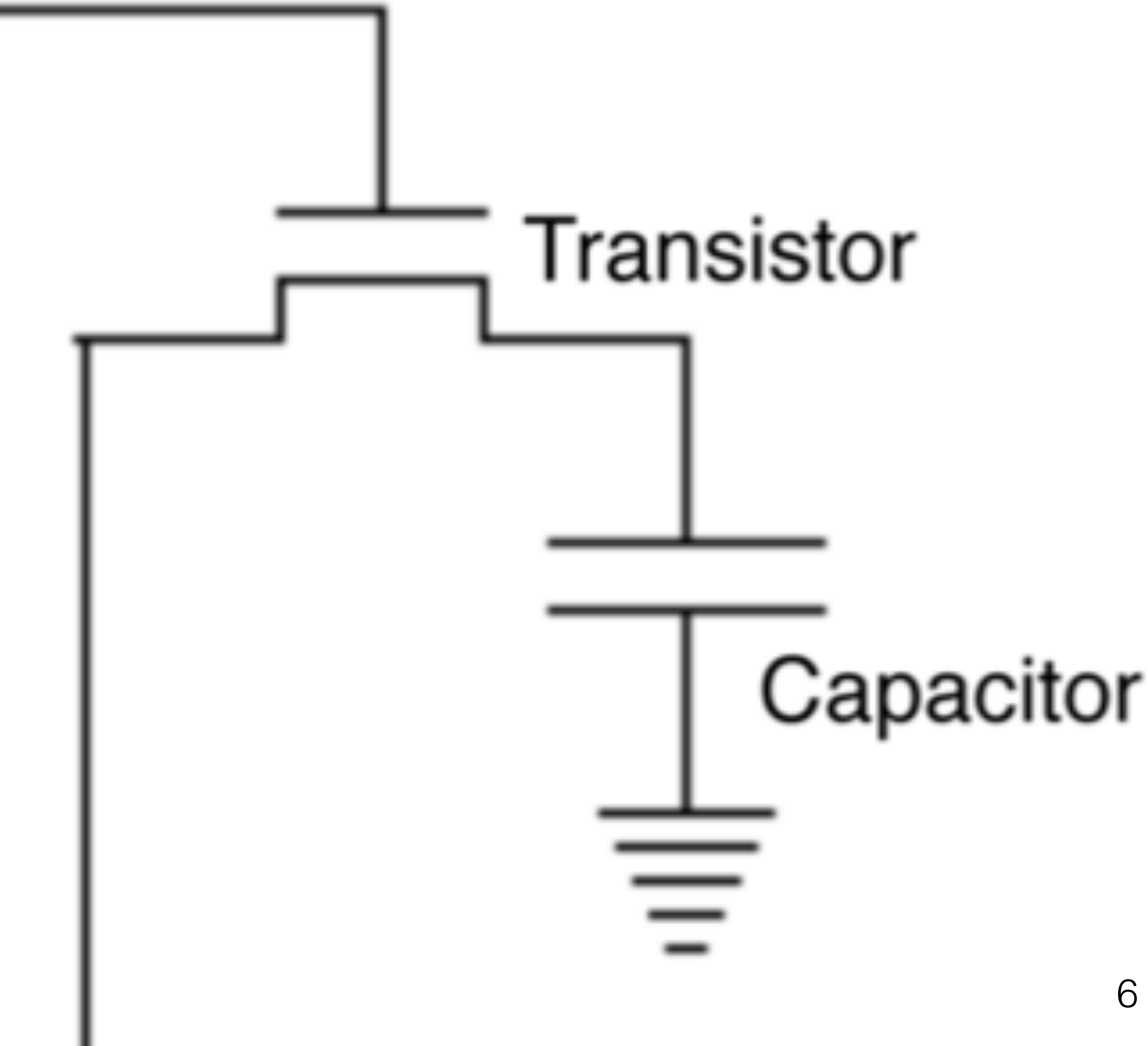

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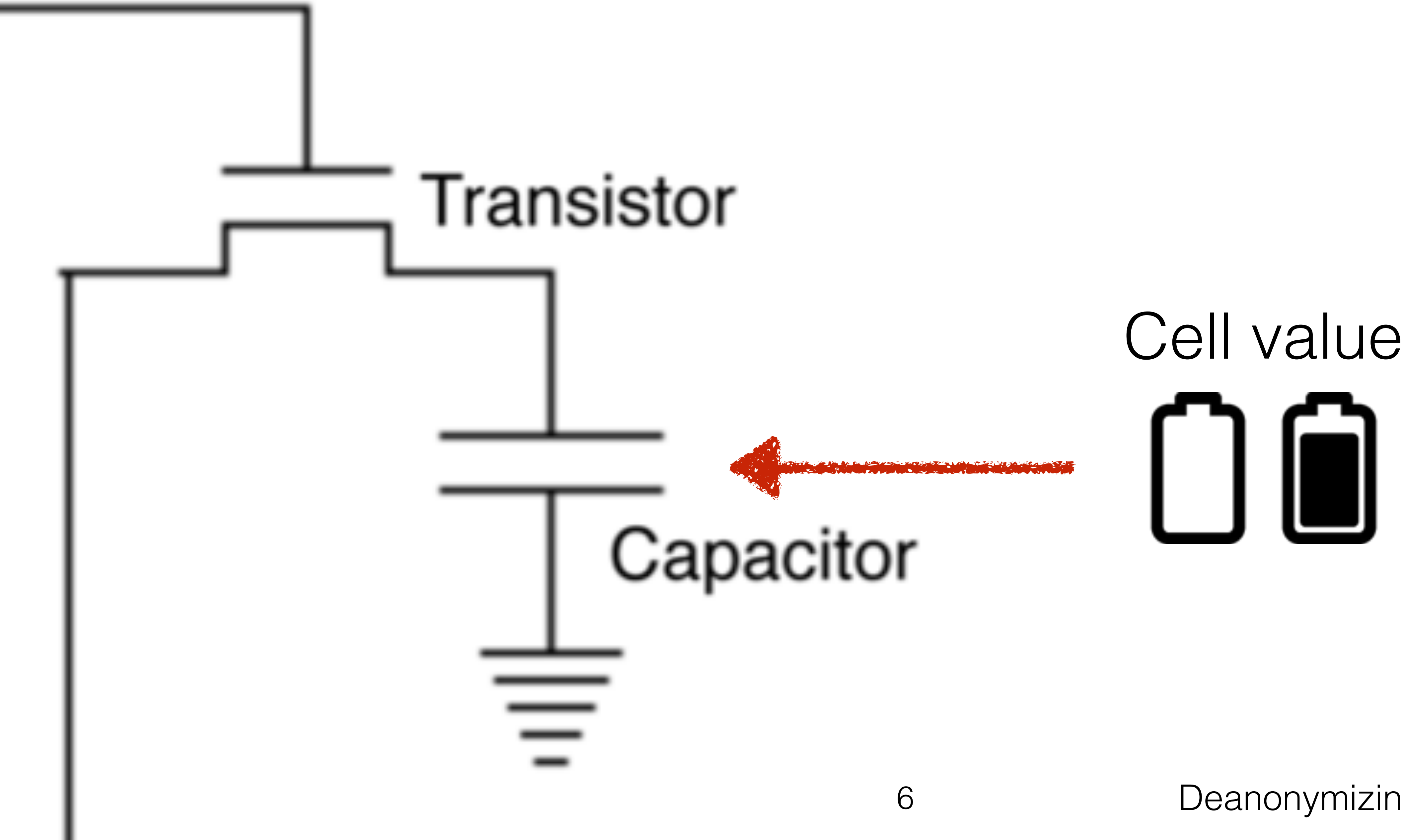
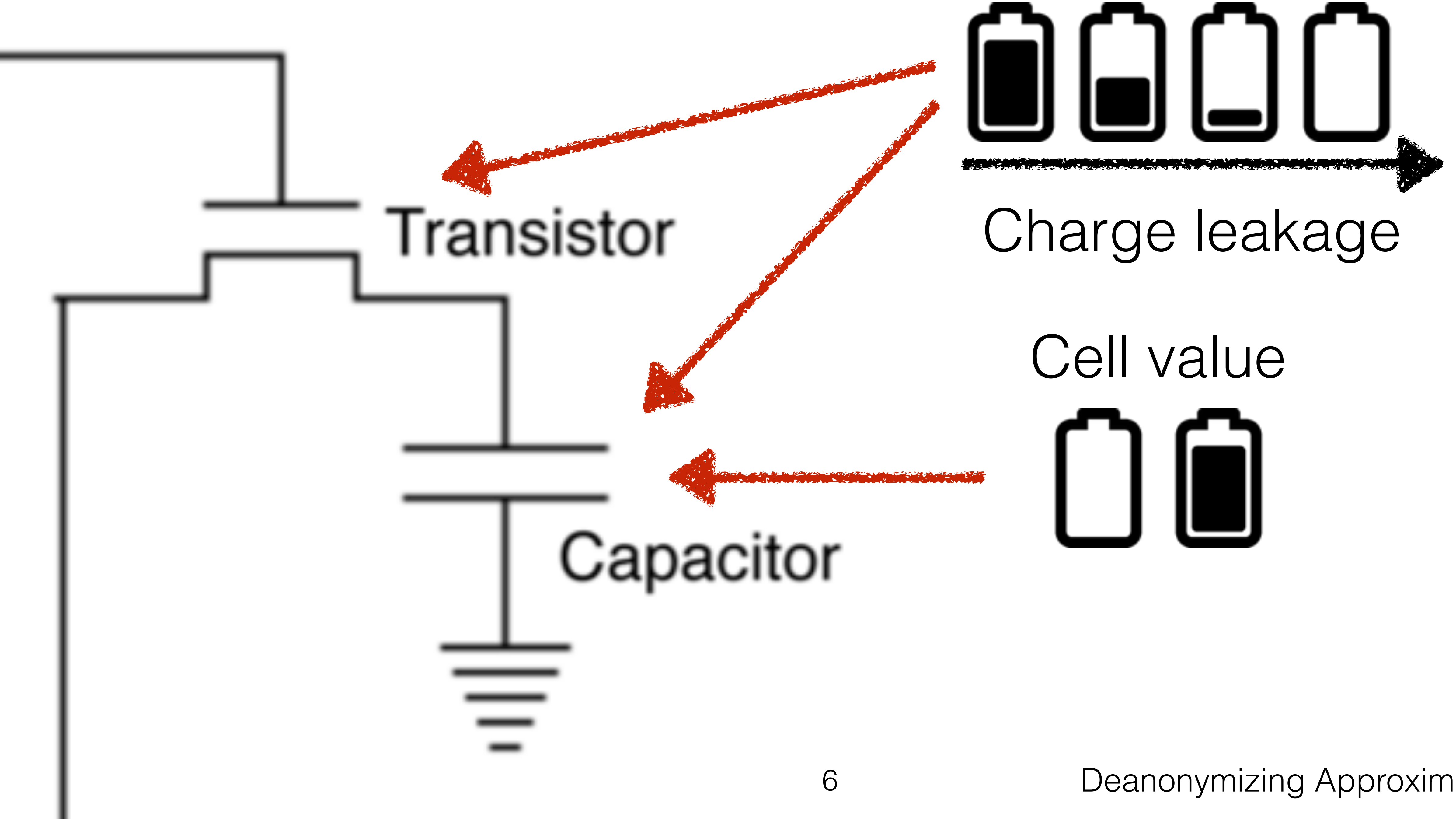


Cell value

Background on DRAM



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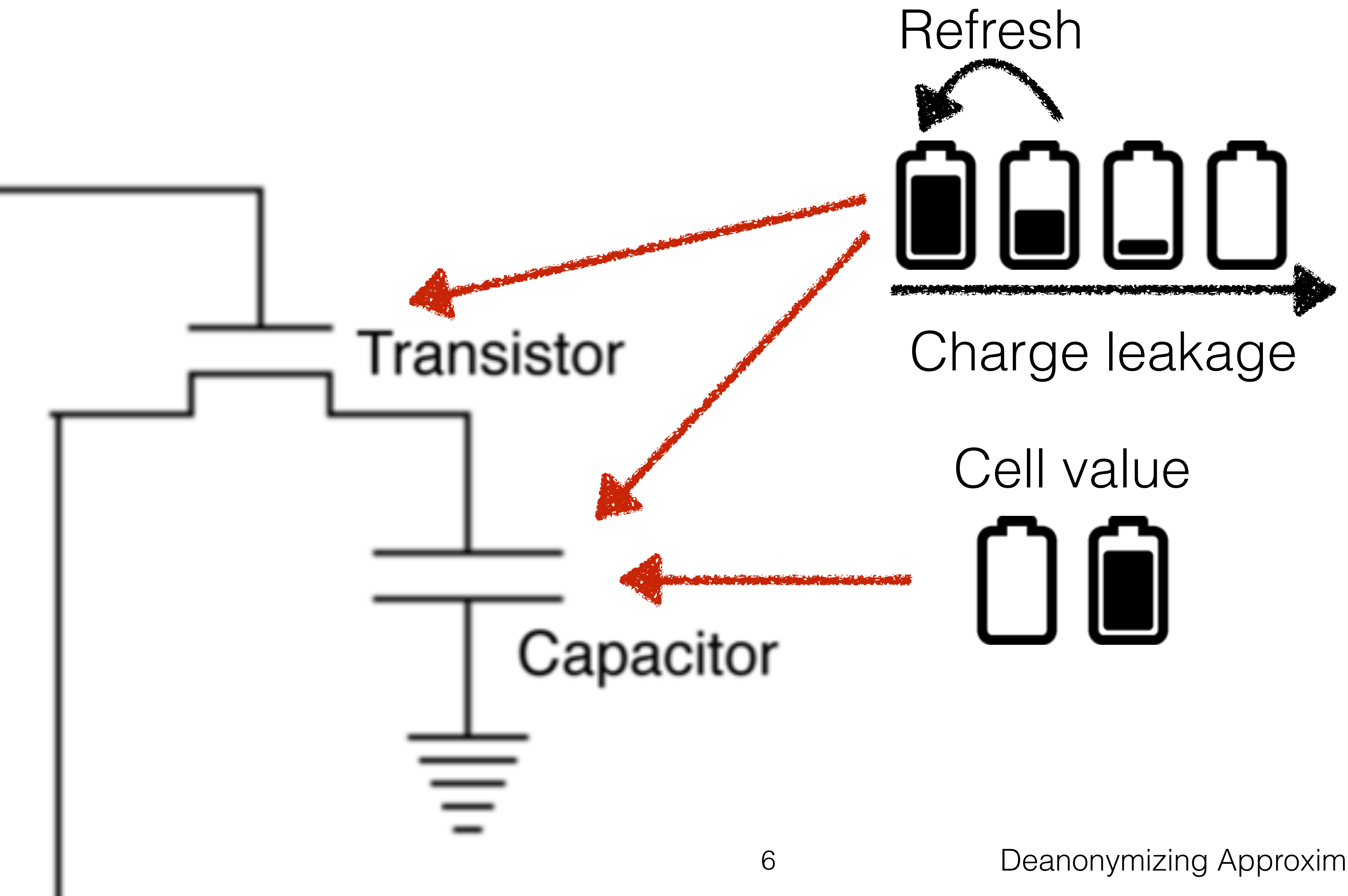

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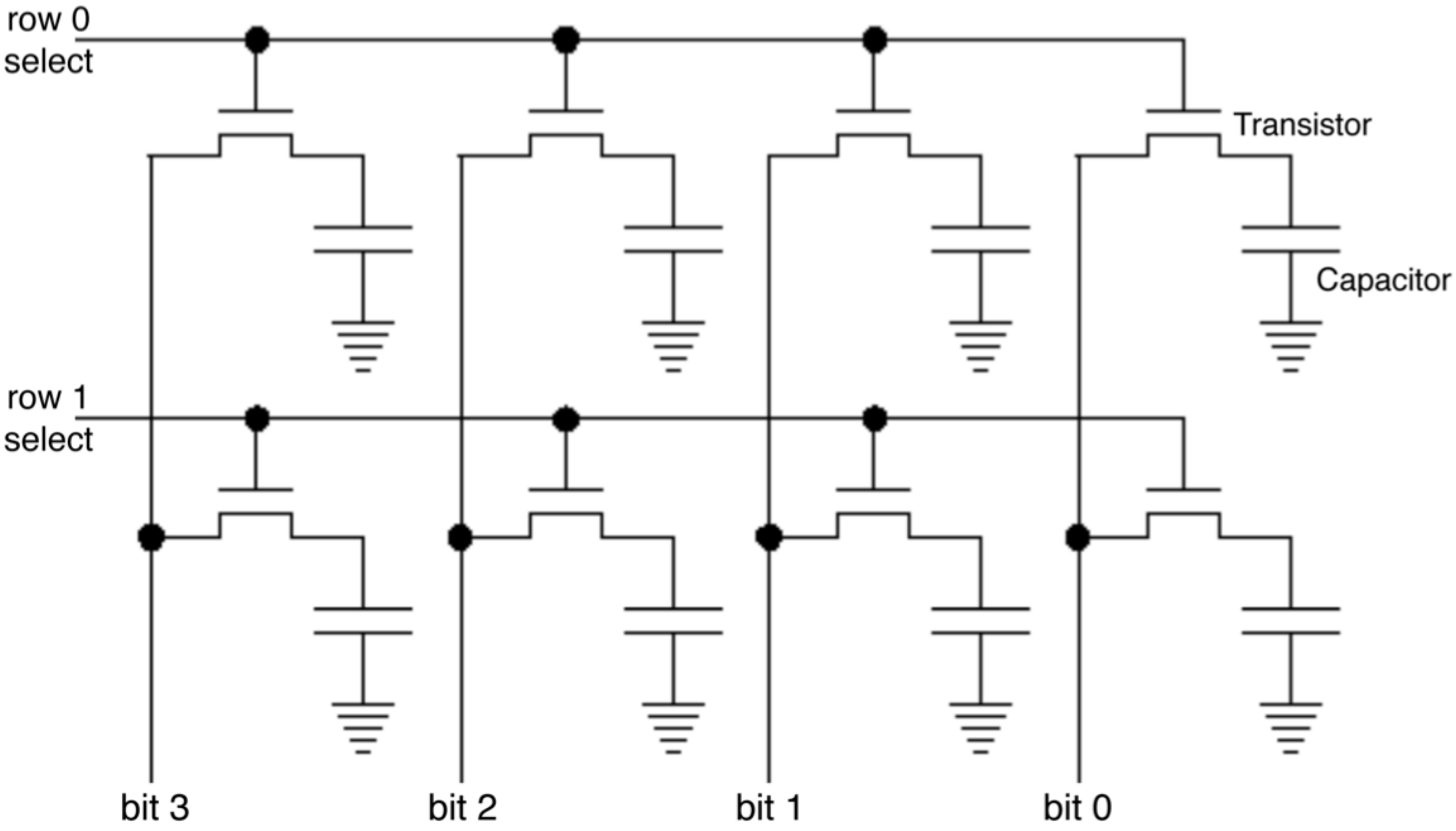

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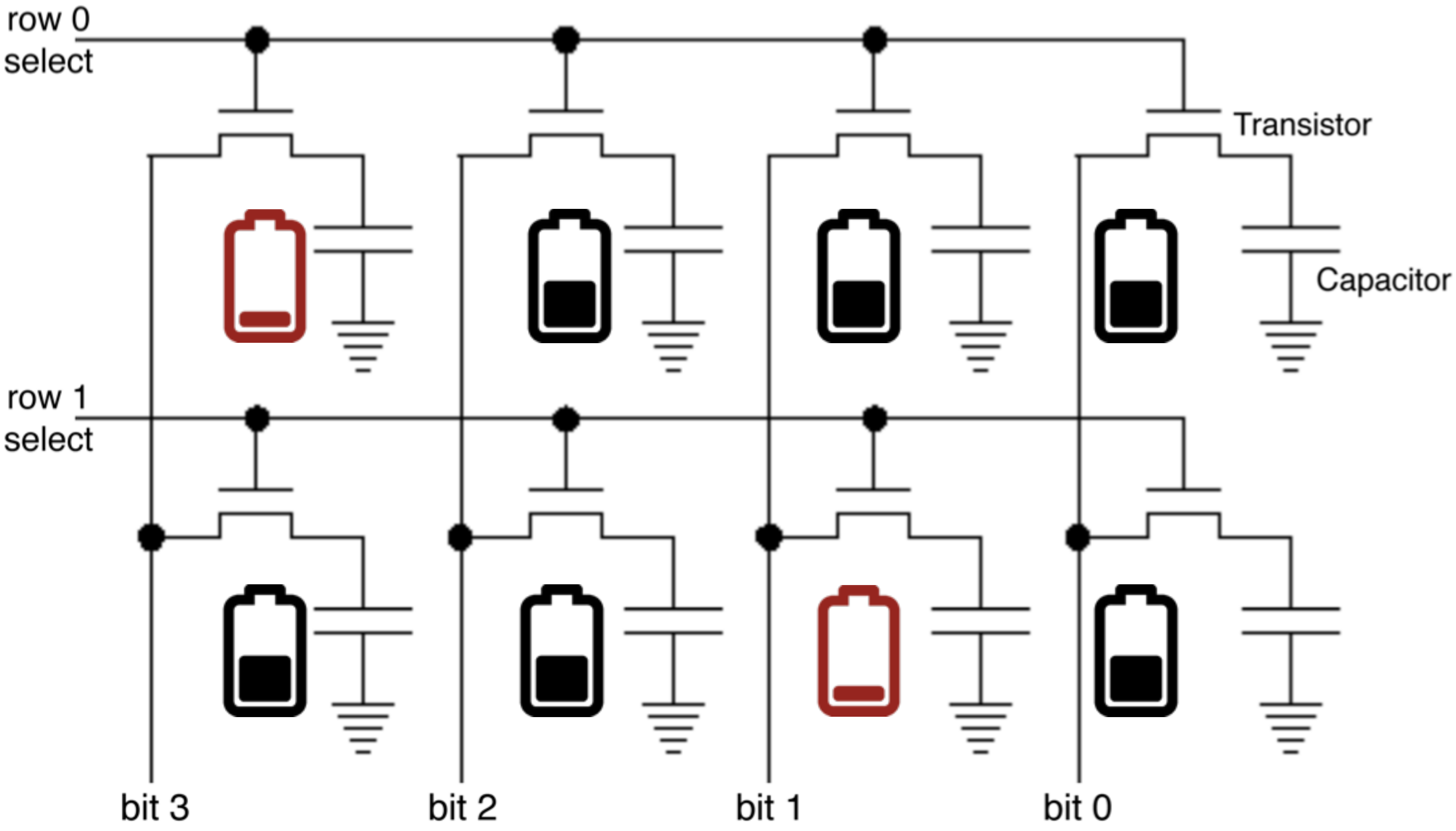
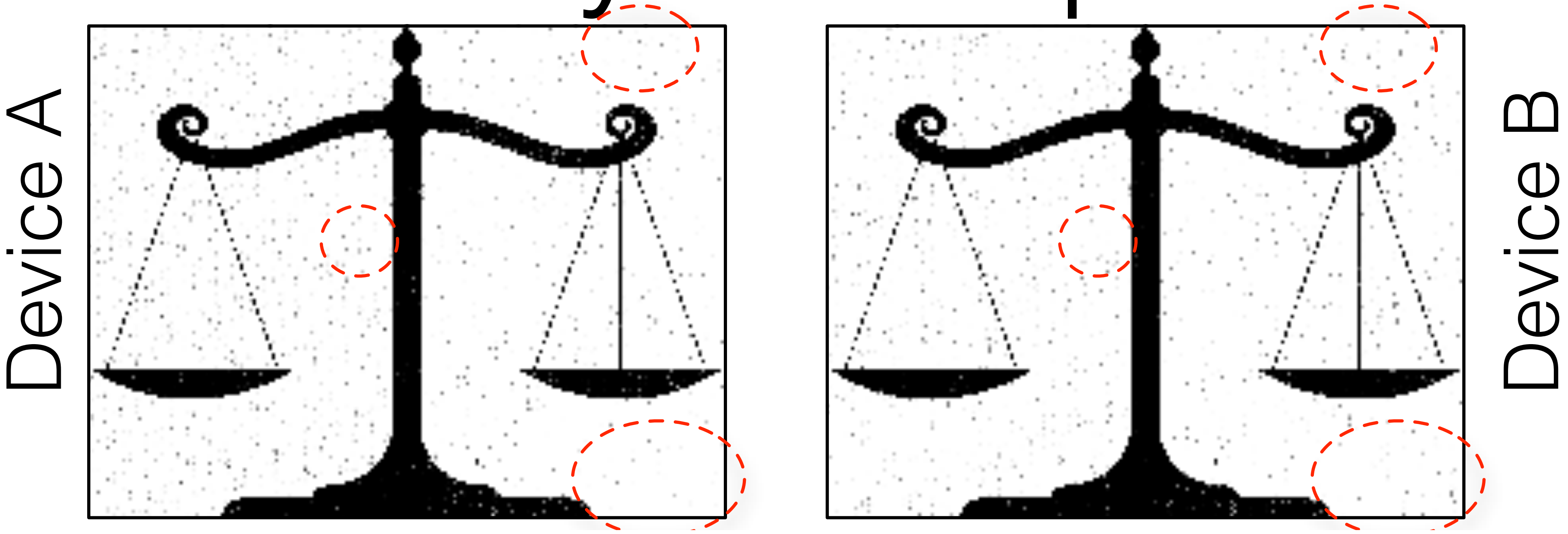


Toy Example



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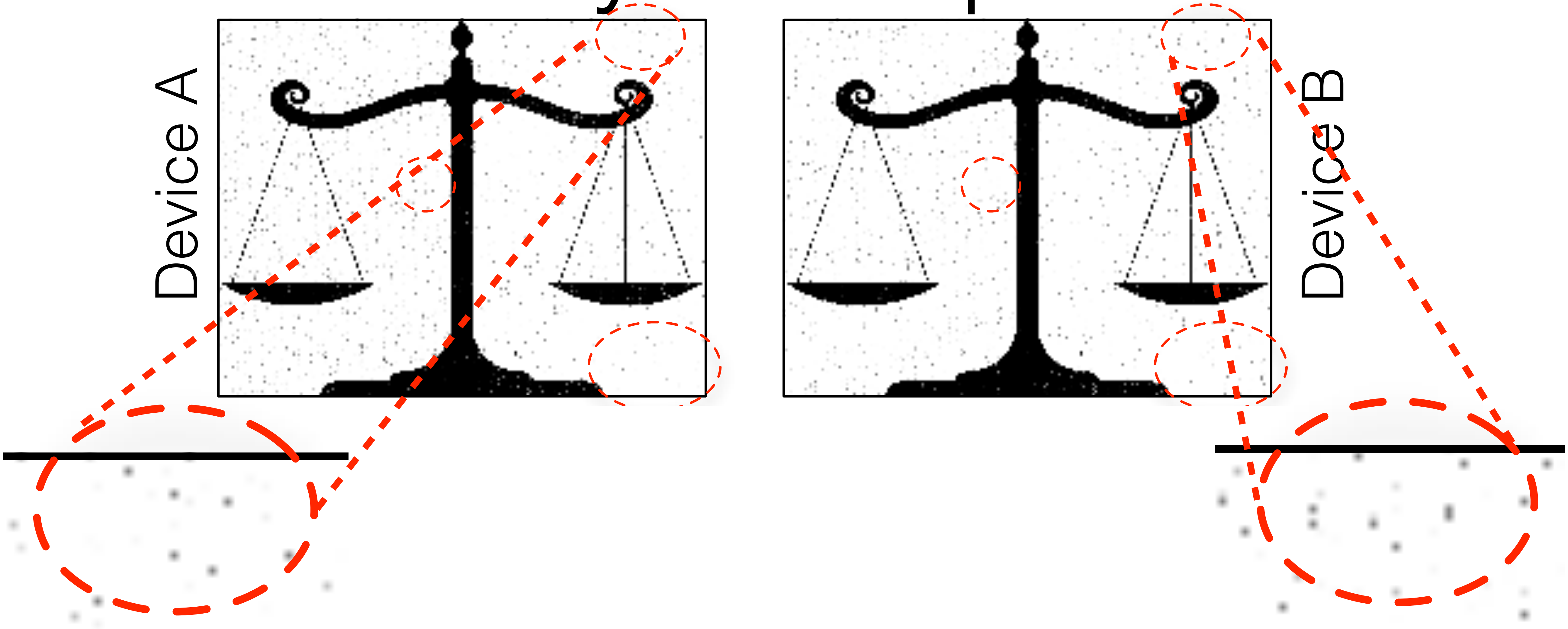

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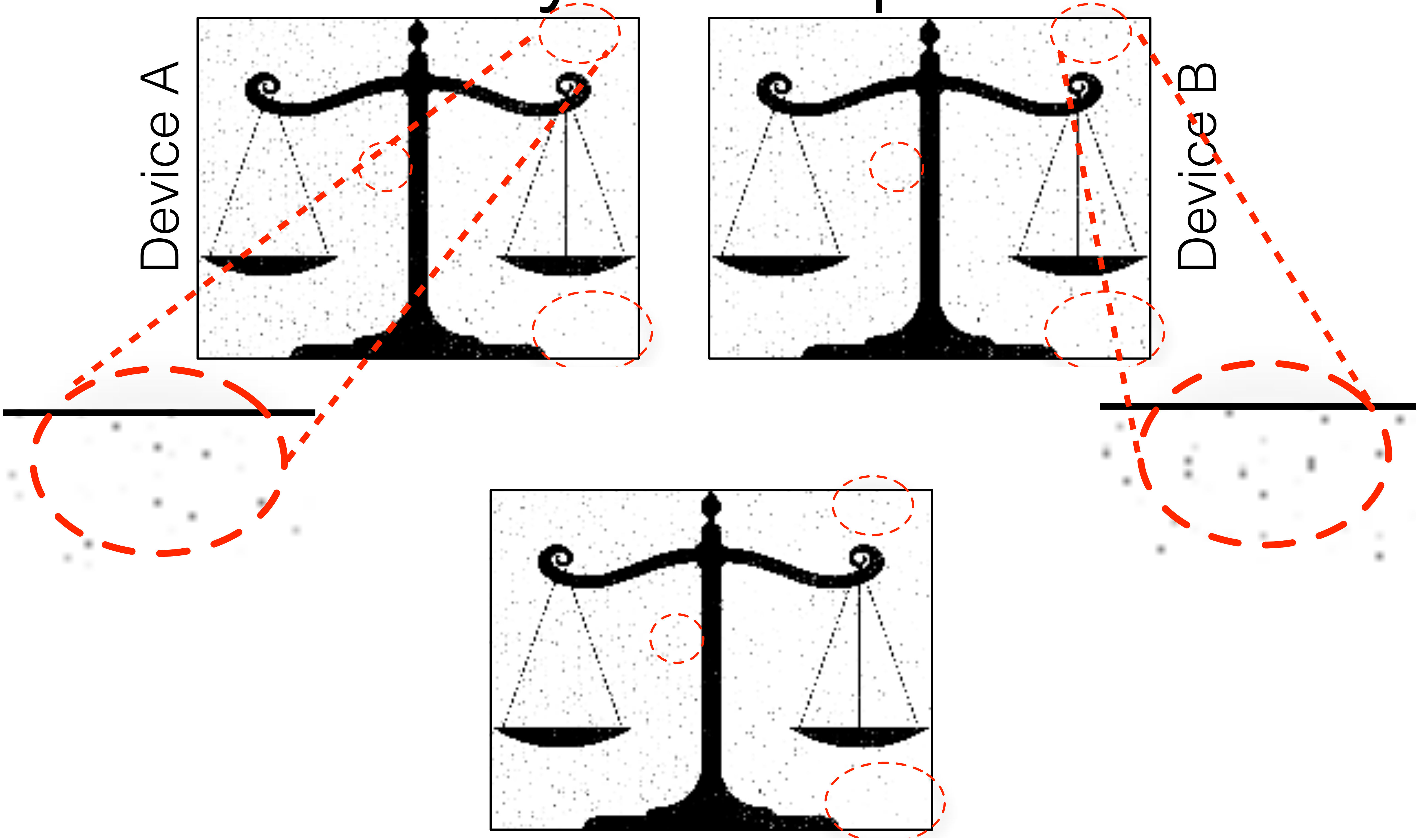

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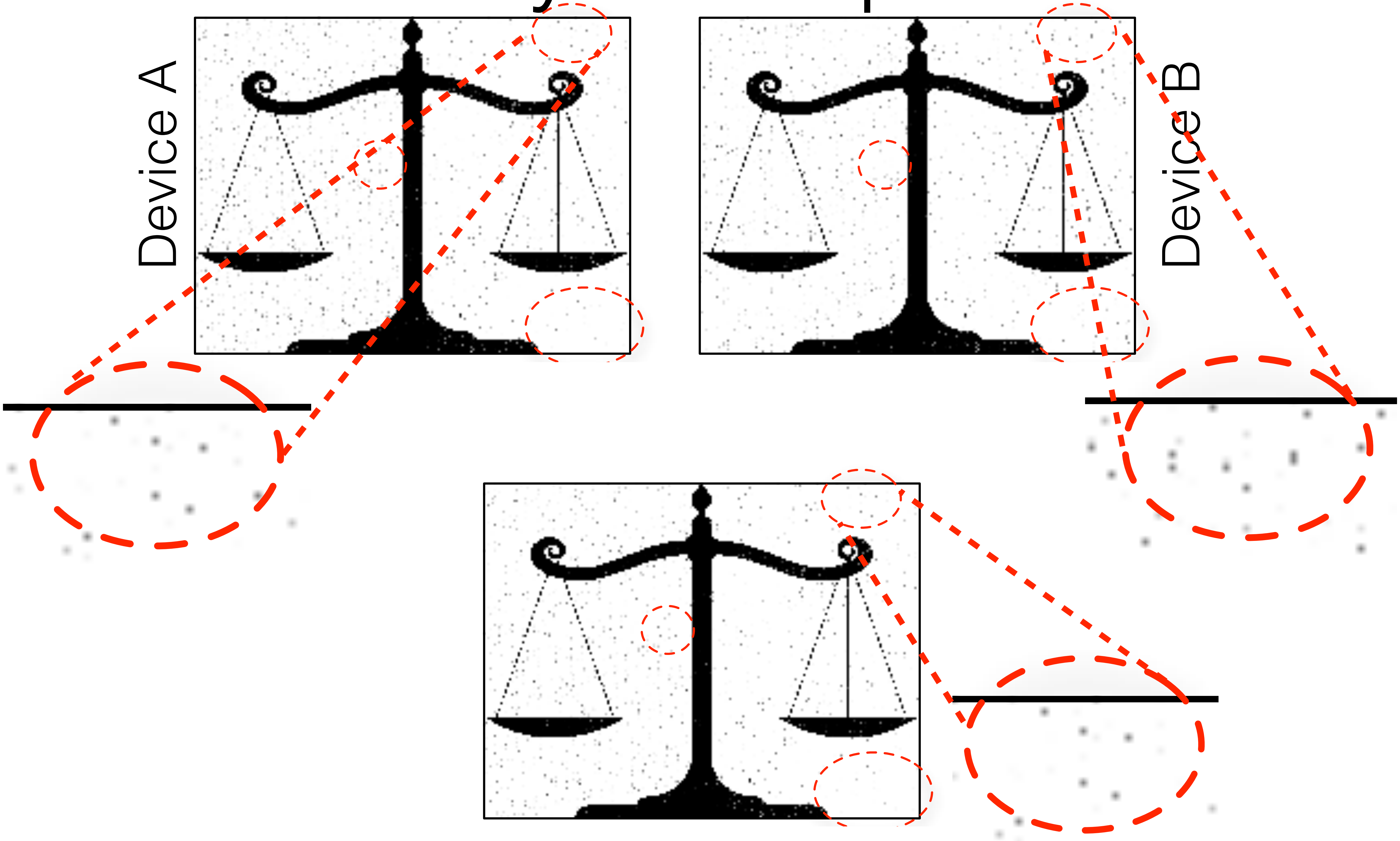

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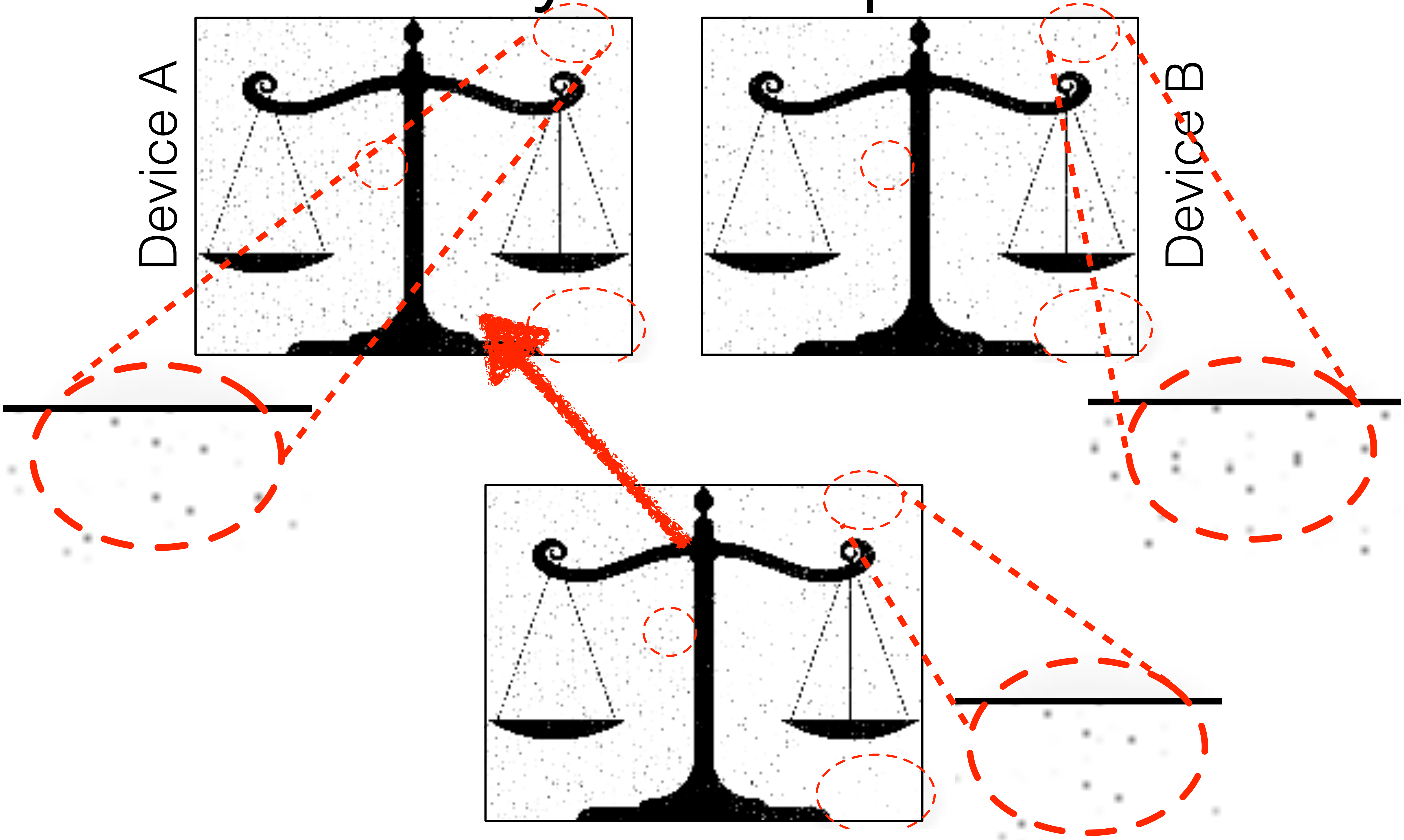

Distance Metric

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Hamming
Distance

Distance Metric

bits

	1	2	3	4	5	6	Hamming Distance
A					x	x	
B				x	x		2

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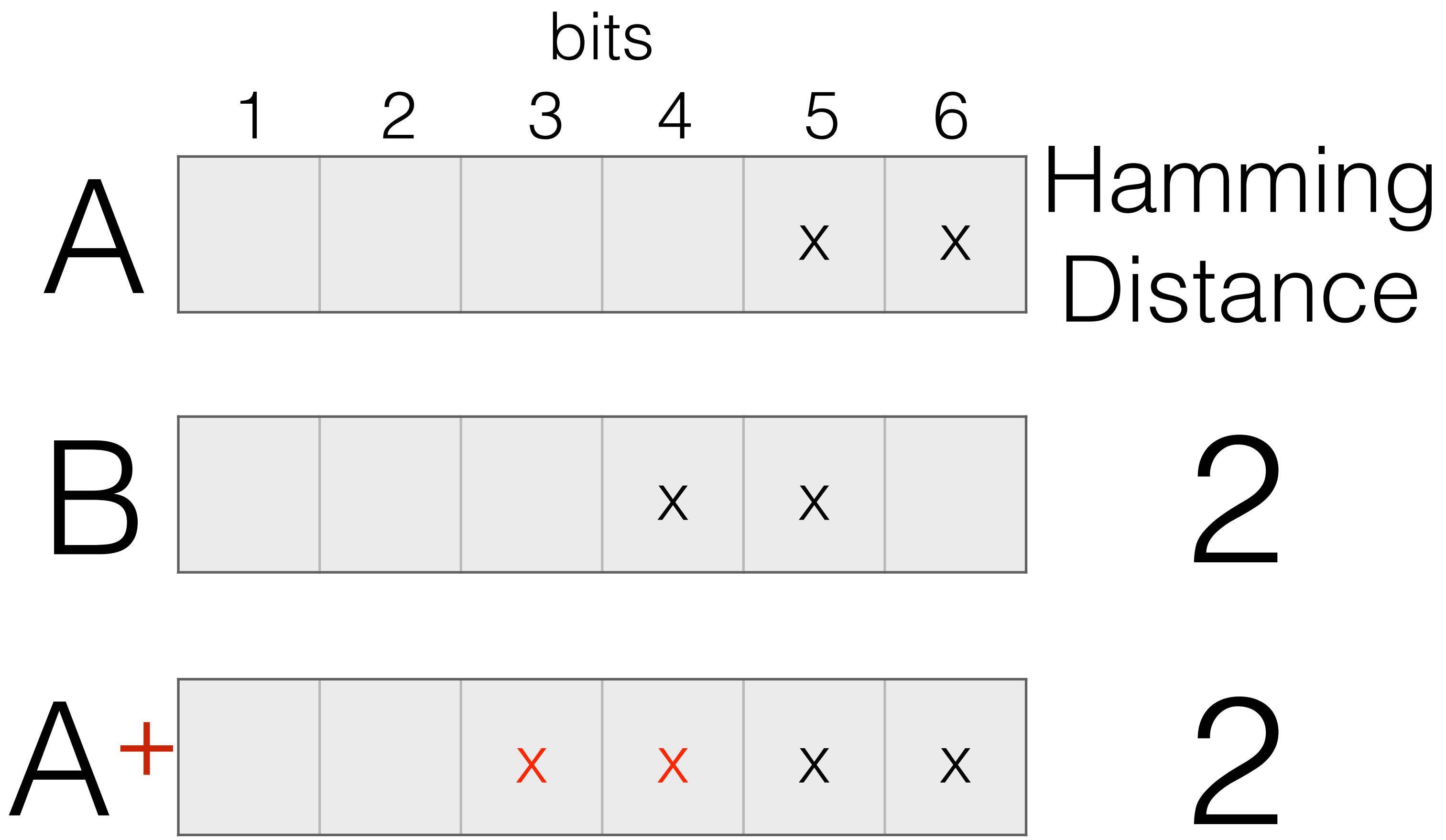

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	1	2	3	4	5	6	Hamming Distance
A					x	x	
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A^+			x	x	x	x	2

Distance Metric

	bits							
	1	2	3	4	5	6	Hamming Distance	Jaccard Distance
A					x	x		
B				x	x		2	1
A^+			x	x	x	x	2	0

Distance Metric

			bits					
	1	2	3	4	5	6	Hamming Distance	Jaccard Distance
A					x	x		
B				x	x		2	1
A^+			x	x	x	x	2	0
C		x		x	x		3	1

Distance Metric

	bits								
	1	2	3	4	5	6	Hamming Distance	Jaccard Distance	$\frac{\text{Jaccard Distance}}{\text{Hamming Weight}}$
A					x	x			
B				x	x		2	1	.5
A^+			x	x	x	x	2	0	0
C		x		x	x		3	1	.33

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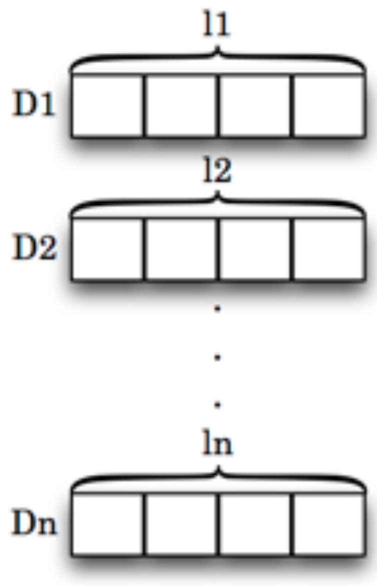
Putting Memory Fingerprint Together

□ Page granularity



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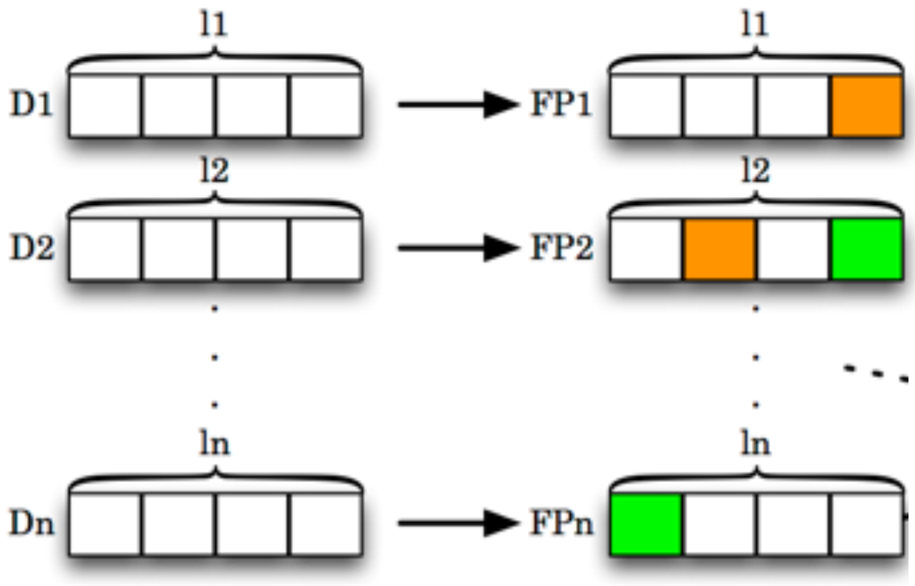

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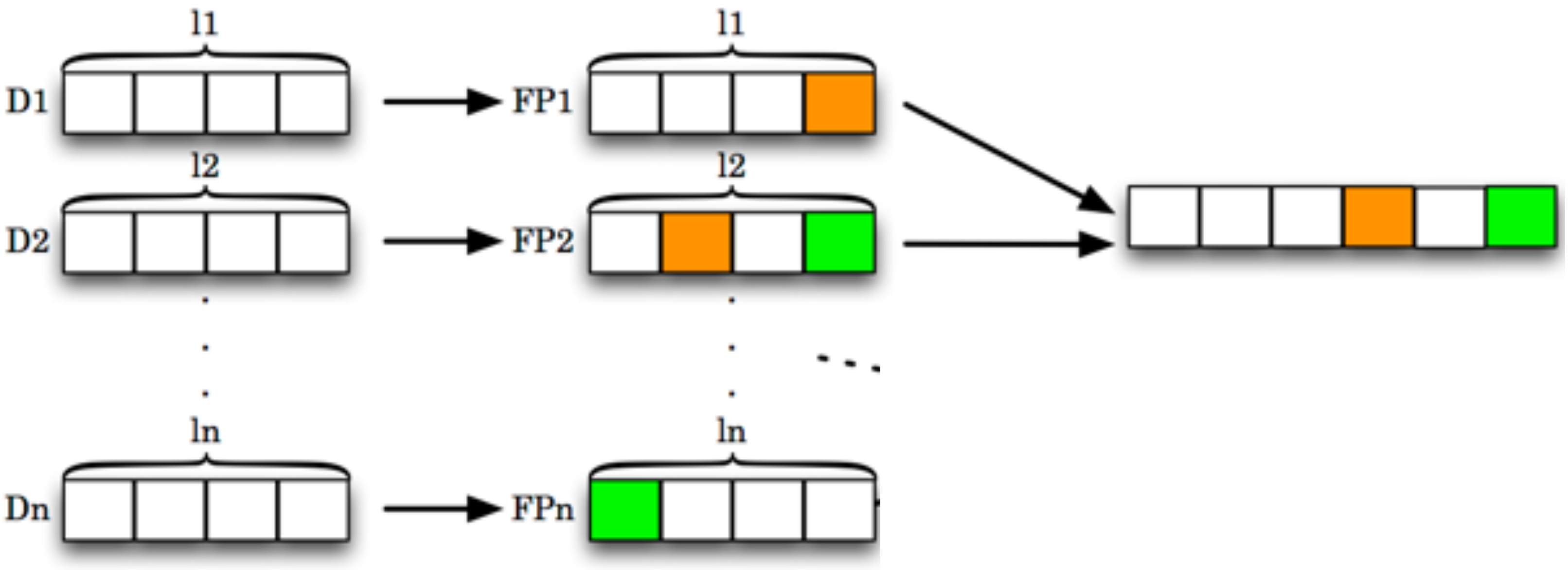

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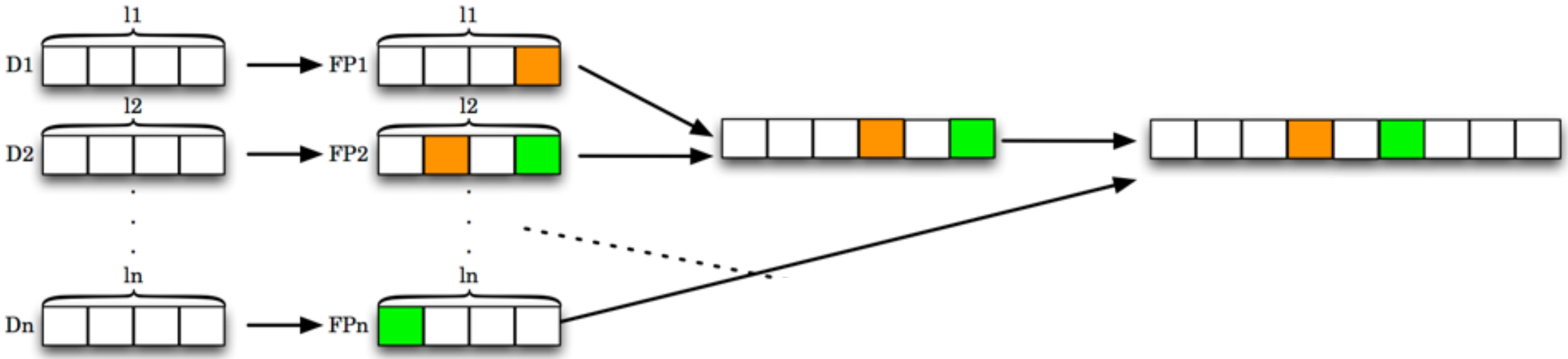

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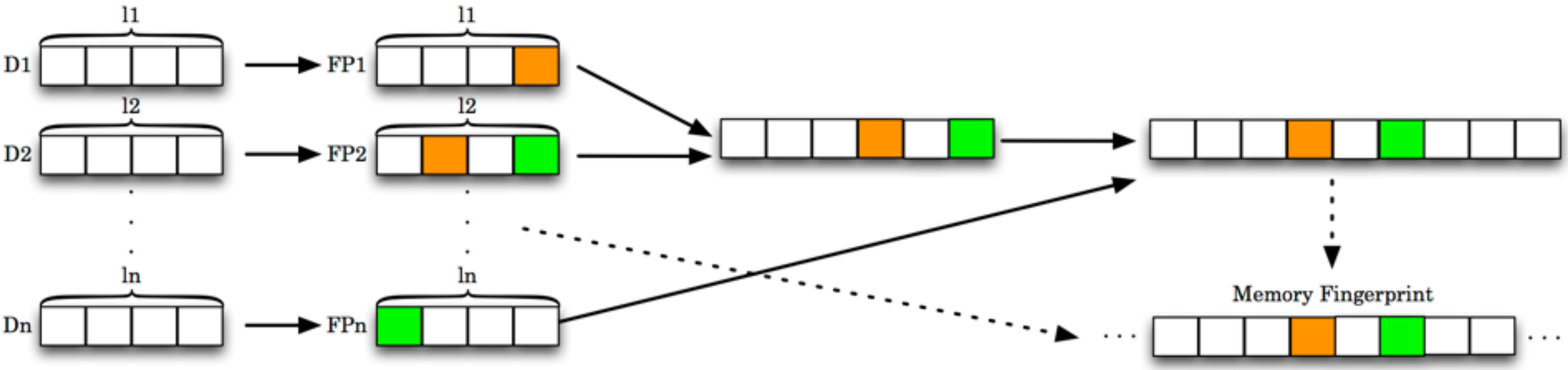
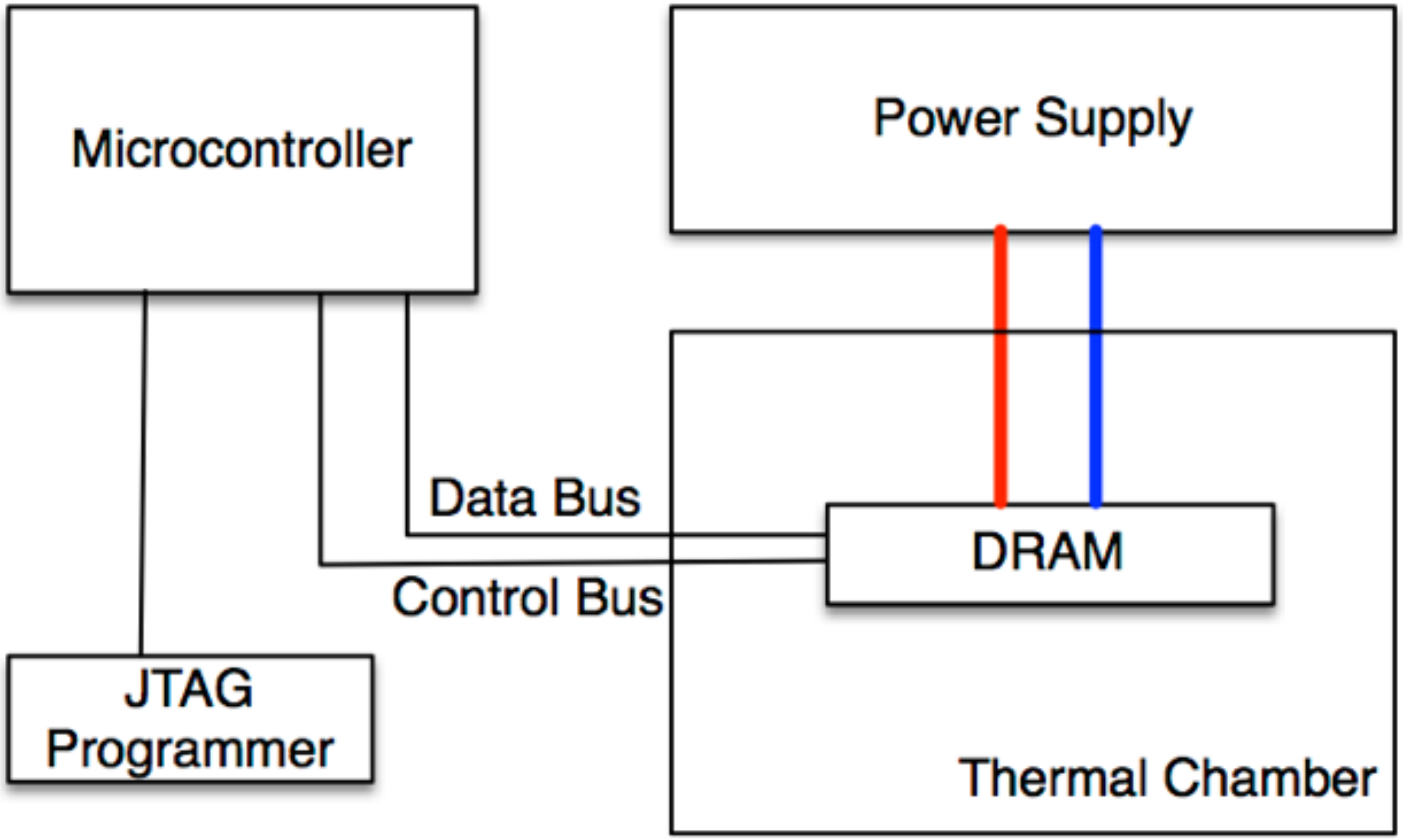
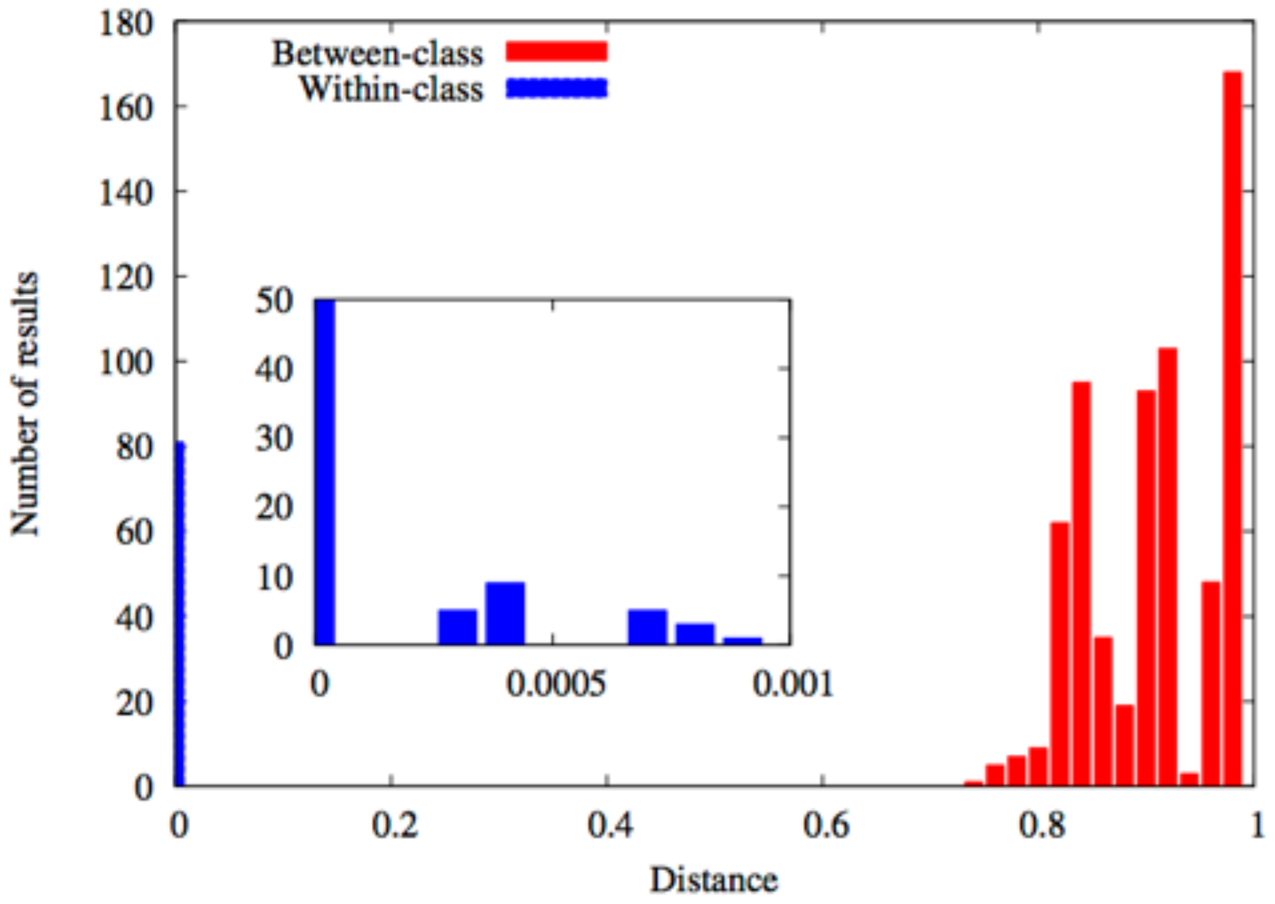


Experimental Setup



Uniqueness

How unique are the fingerprints?



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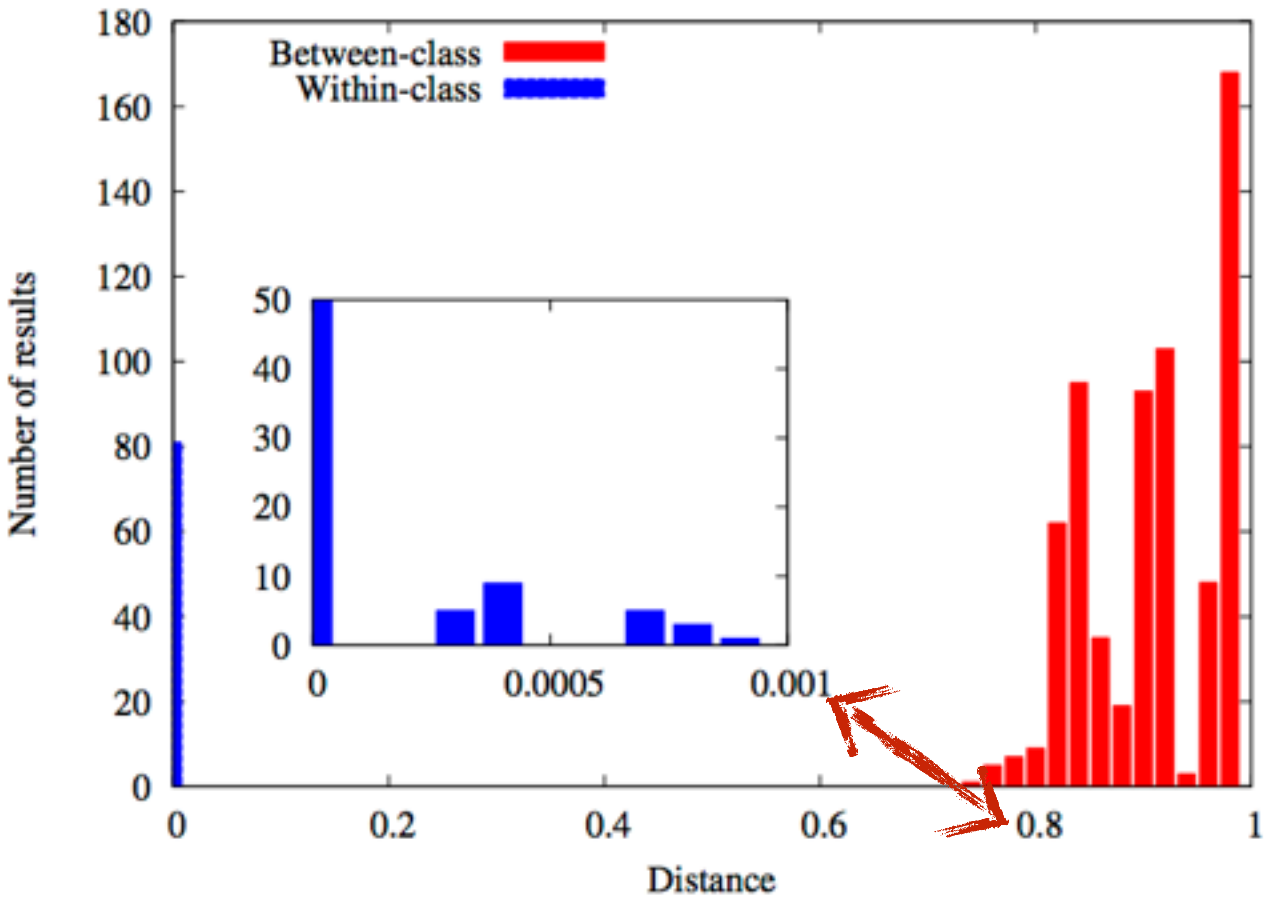

Two order of magnitude difference

Order of Failure

Does the fingerprint hold across different levels of approximation?

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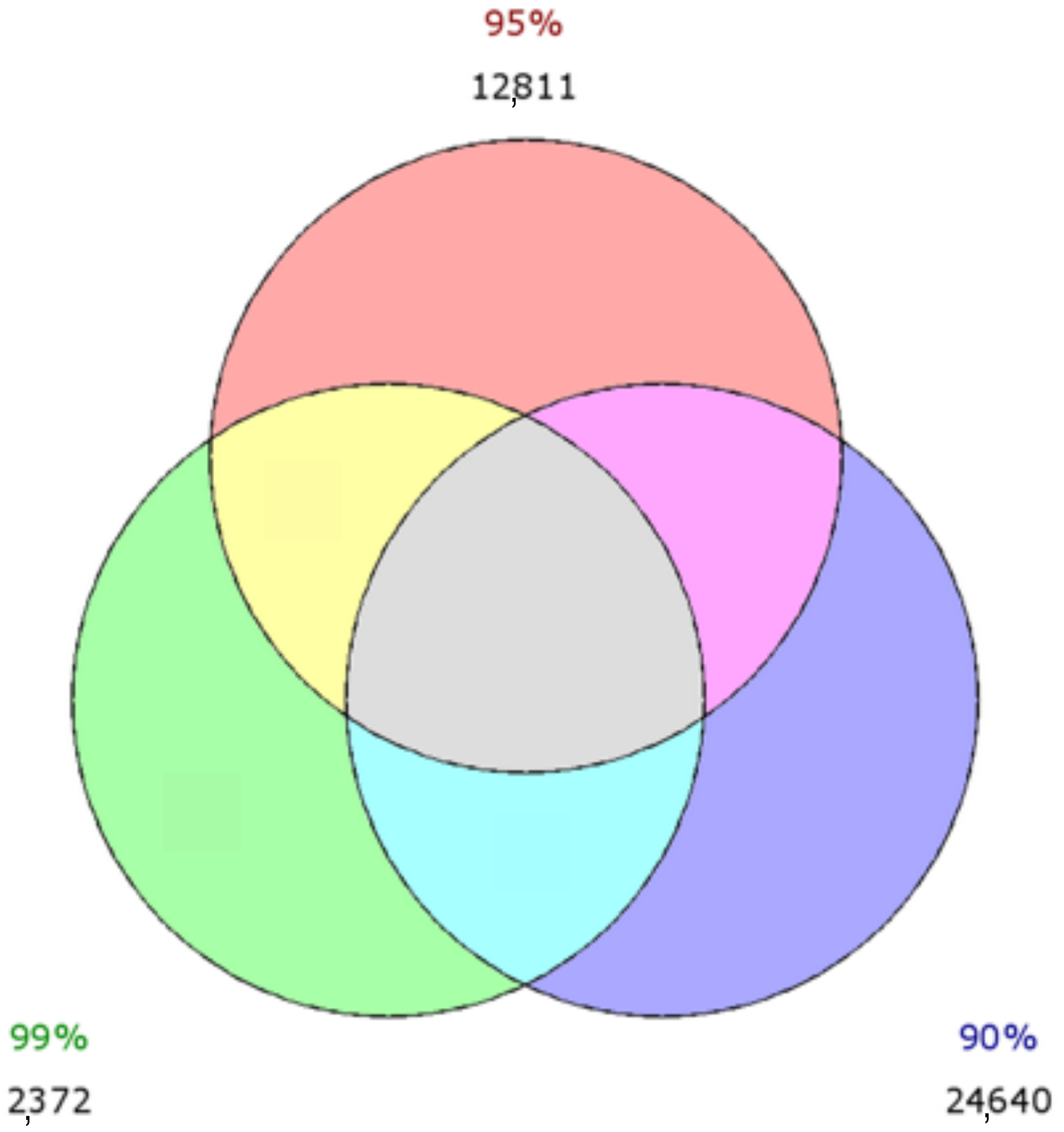

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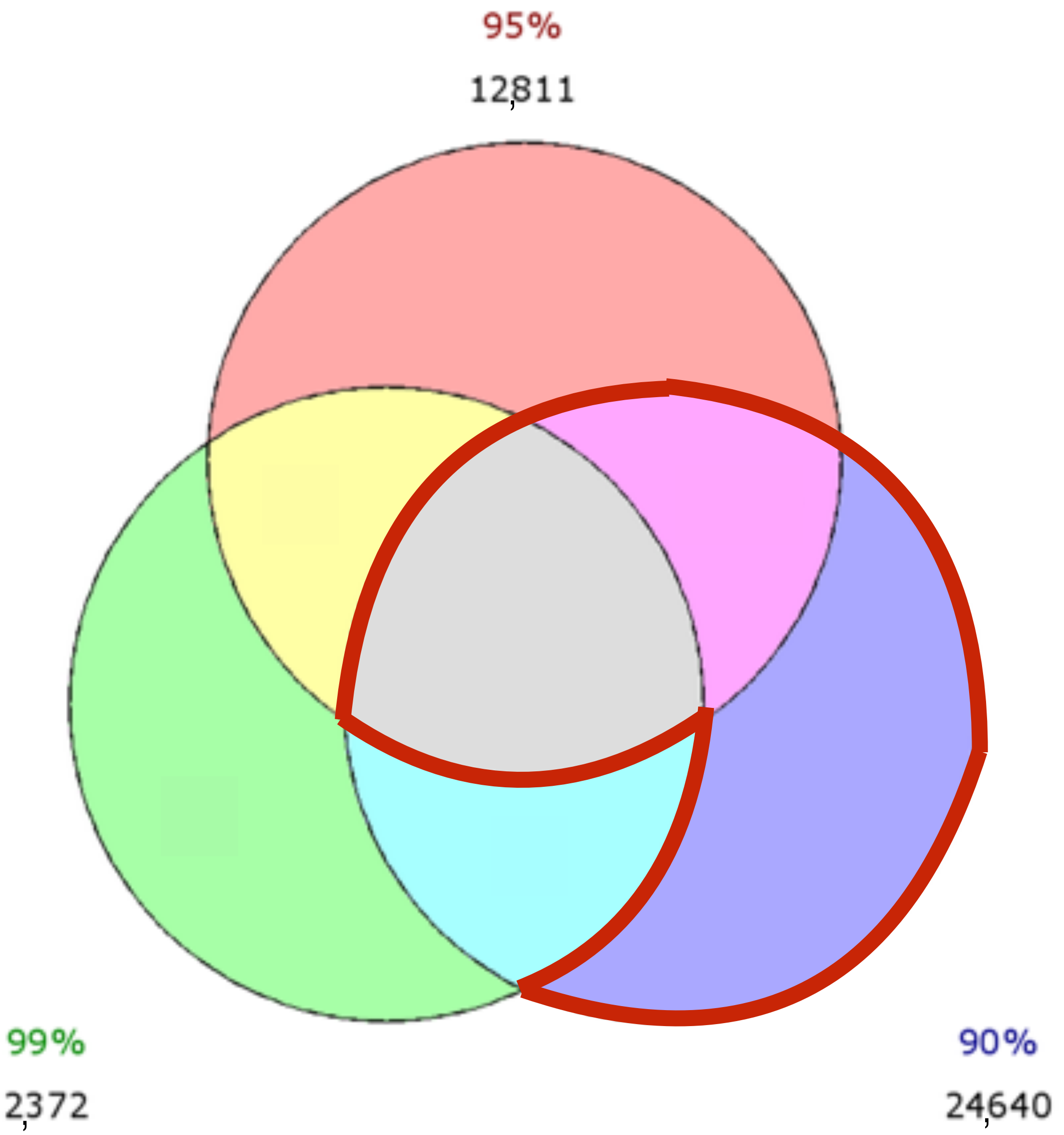

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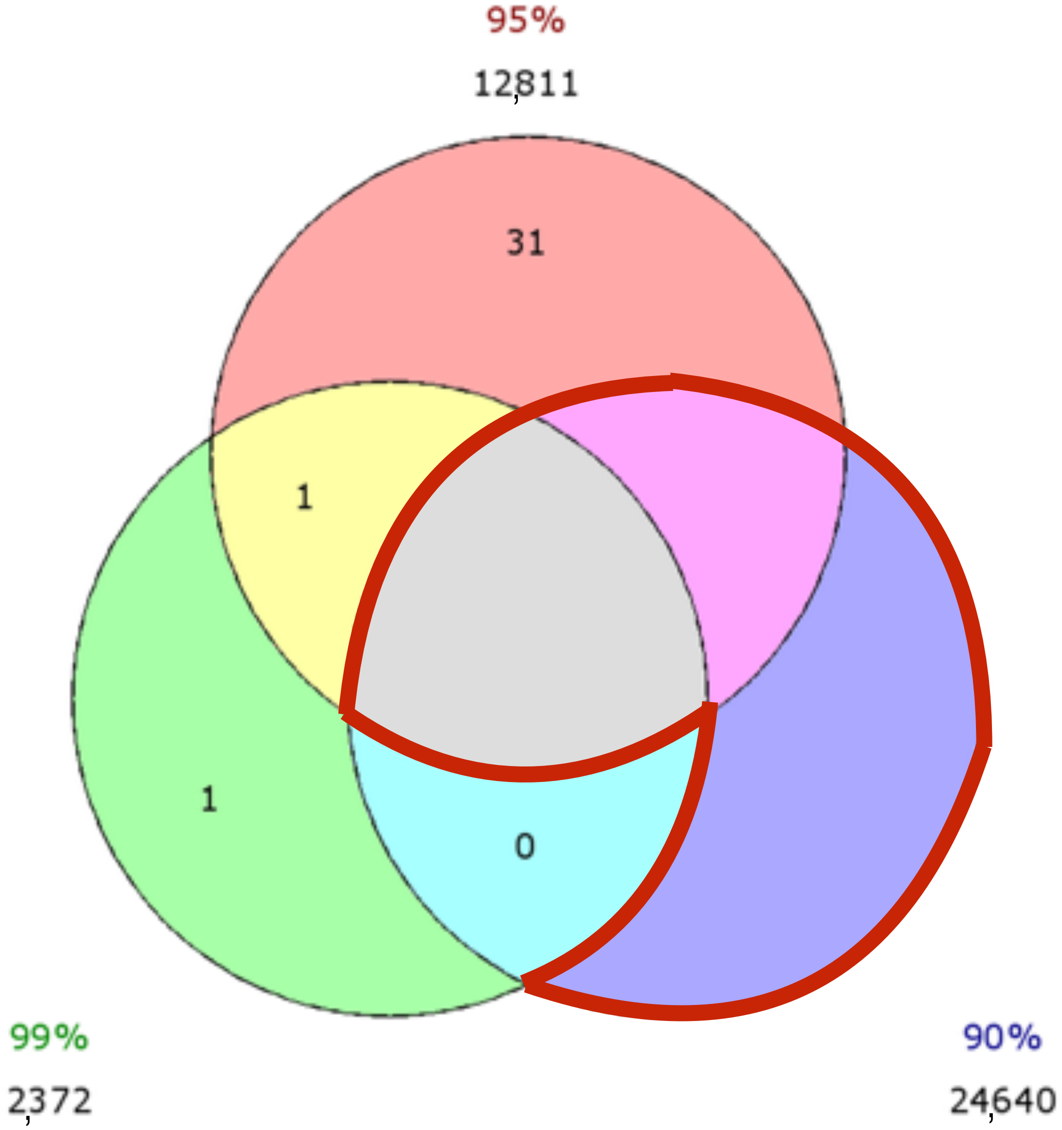

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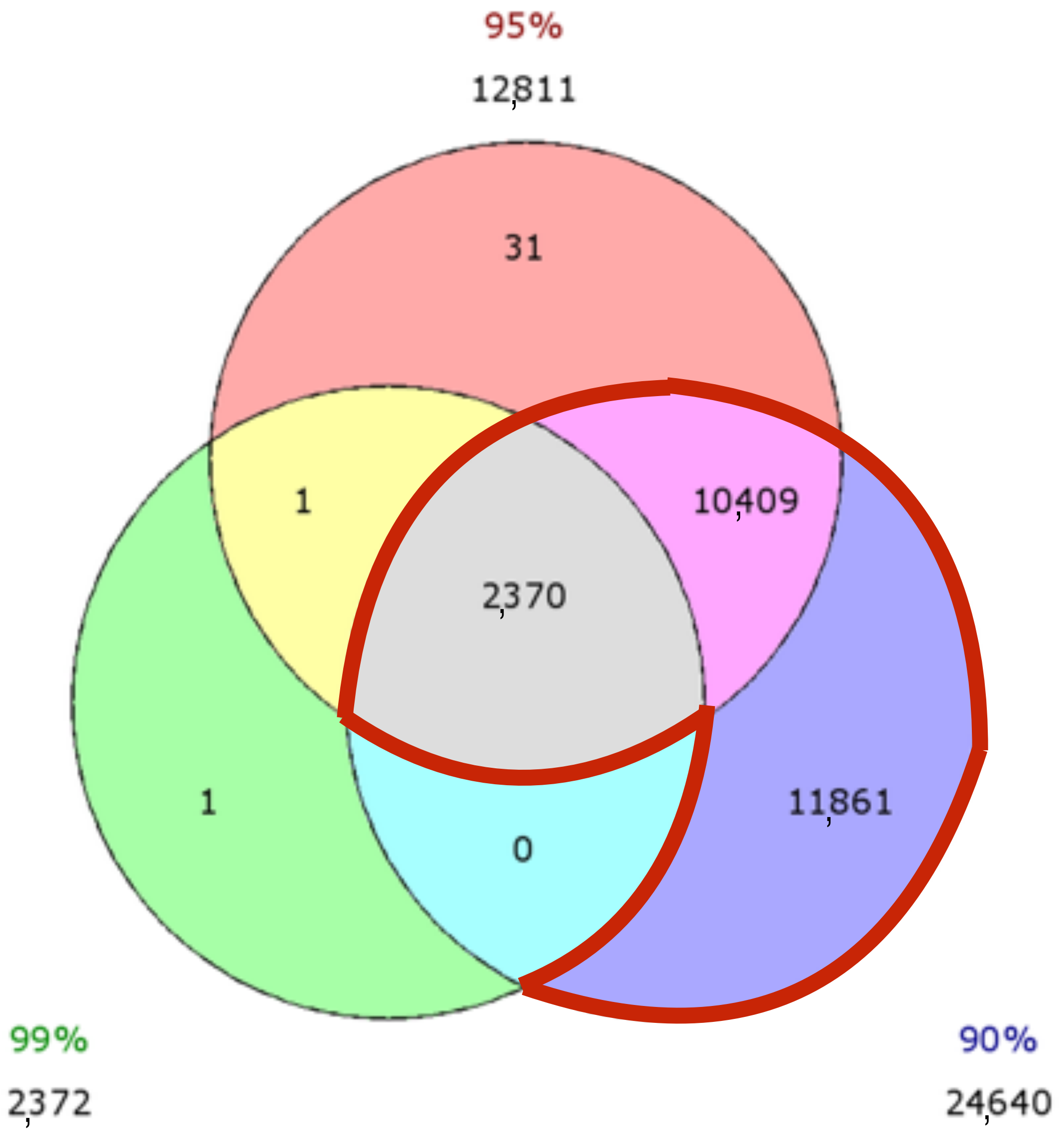

Level of Approximation

How do different levels of approximation affect identification?

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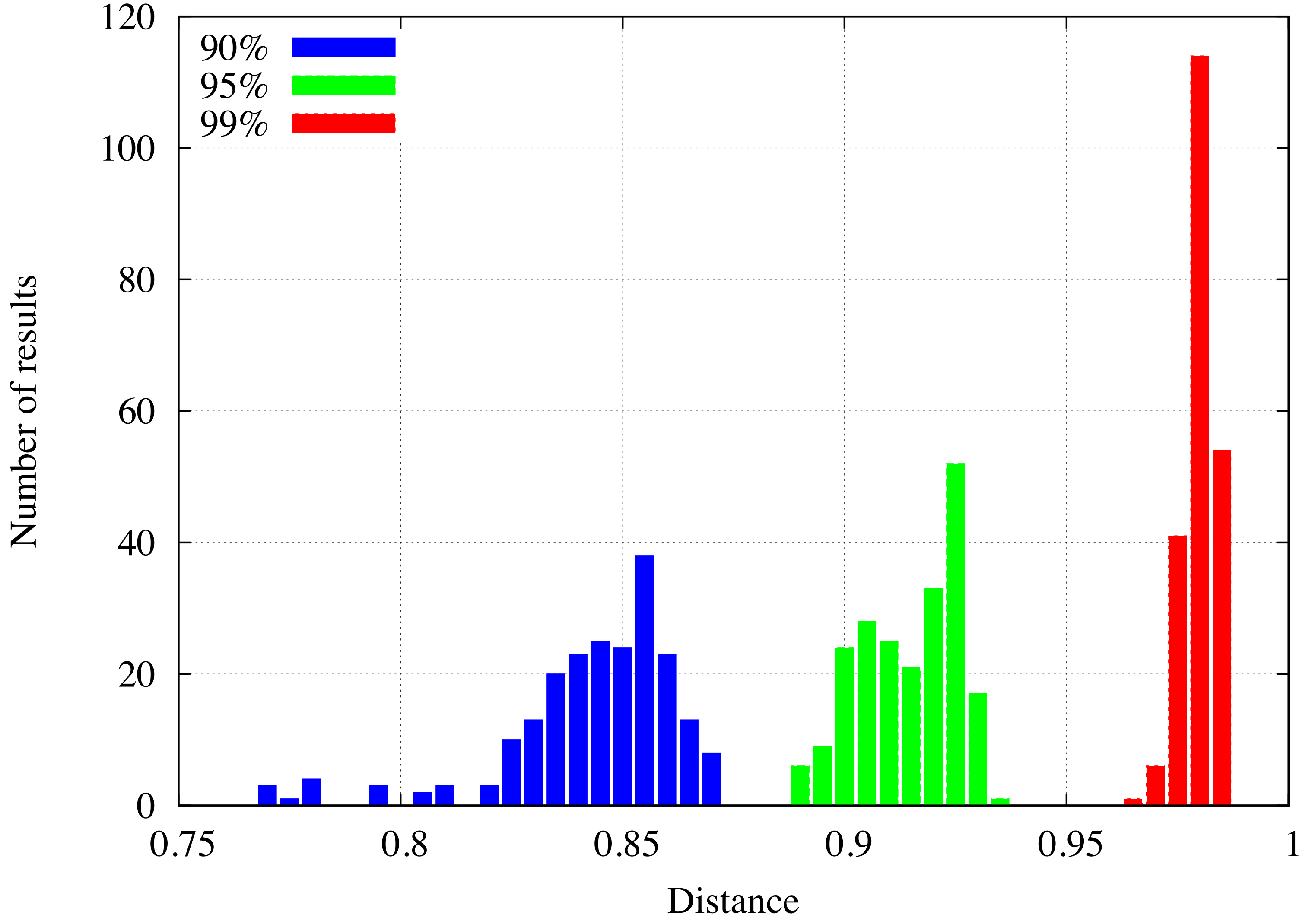

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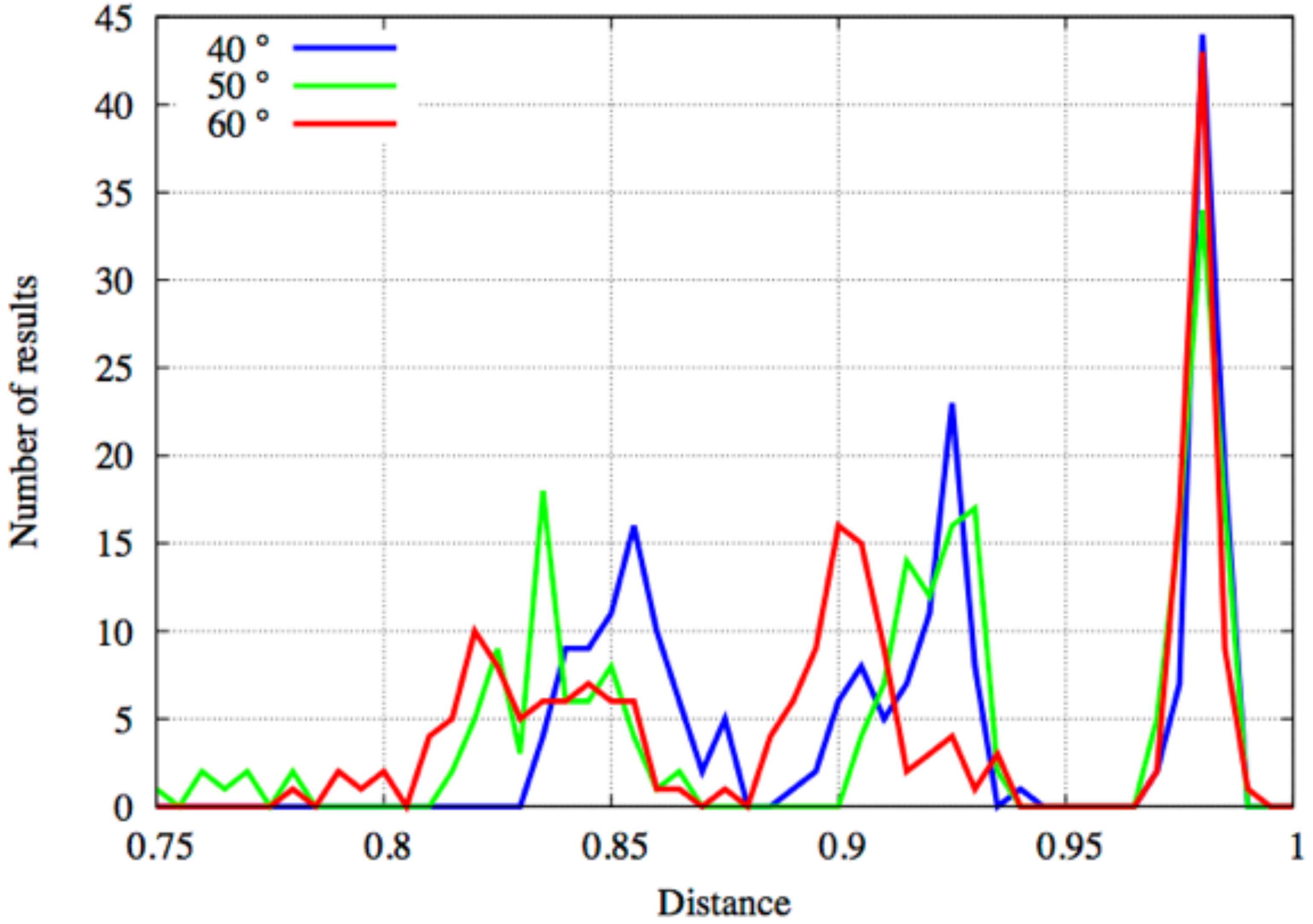

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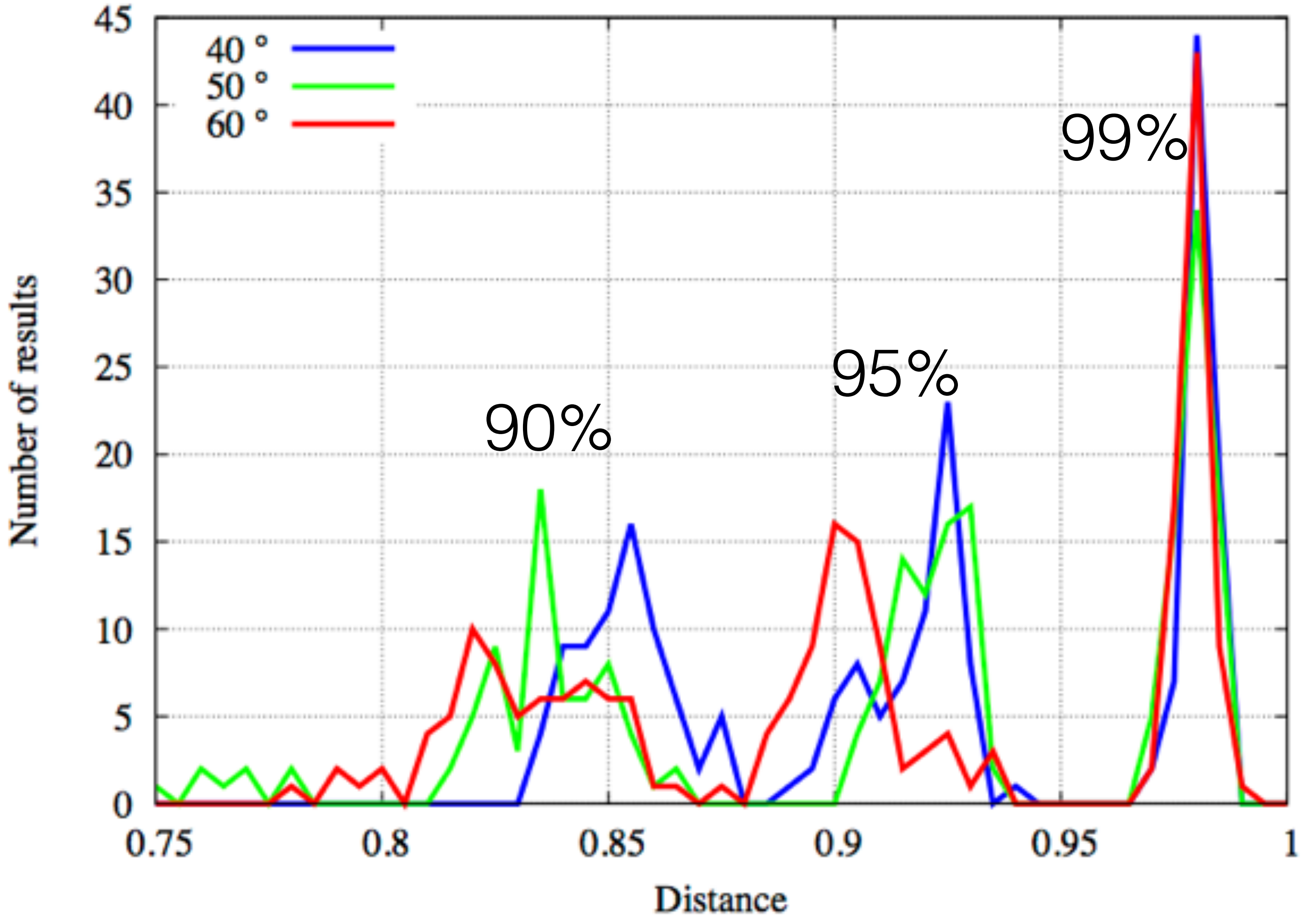

90%

95%

99%

Consistency

How consistent are the fingerprints?

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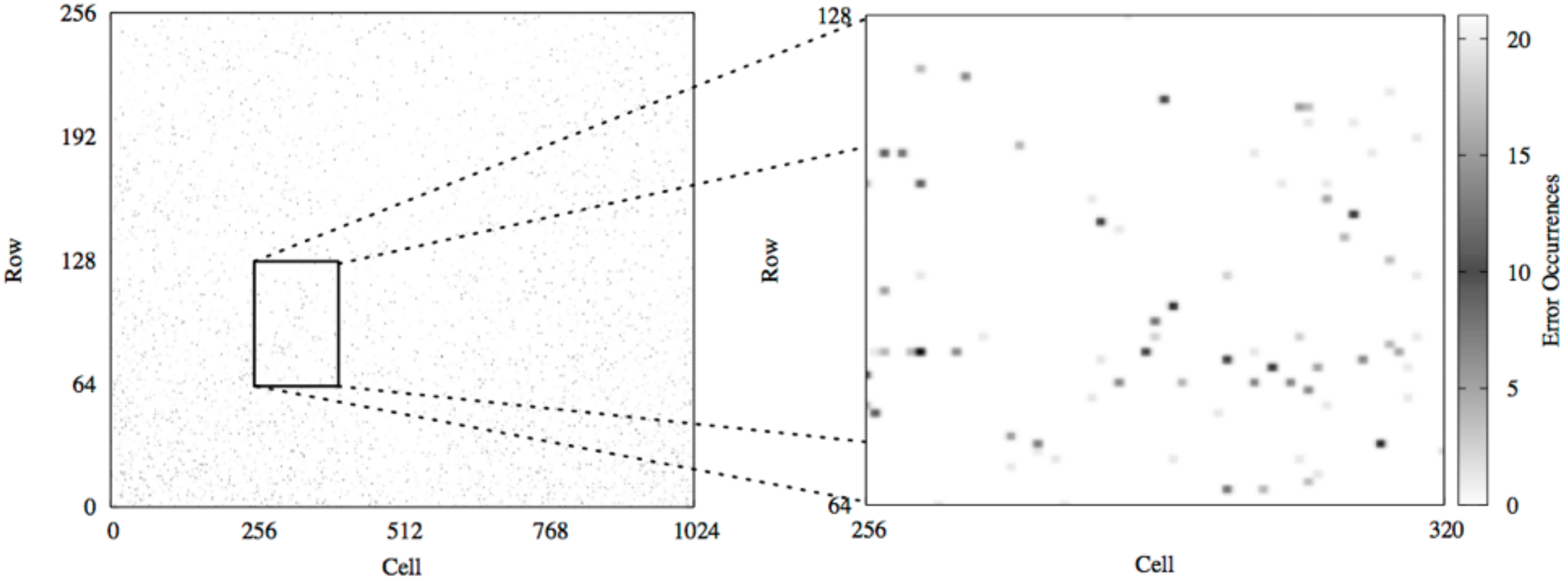
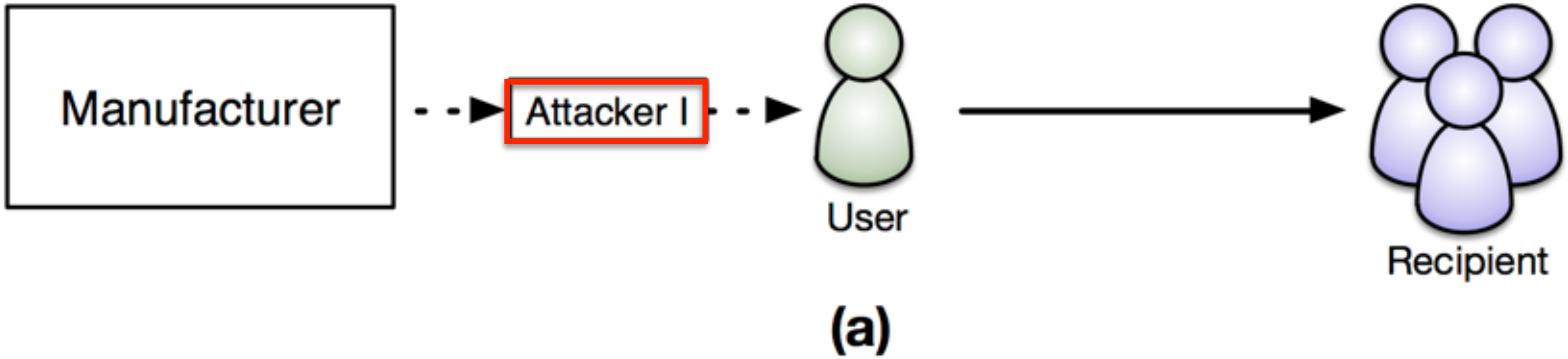


Types of Attack



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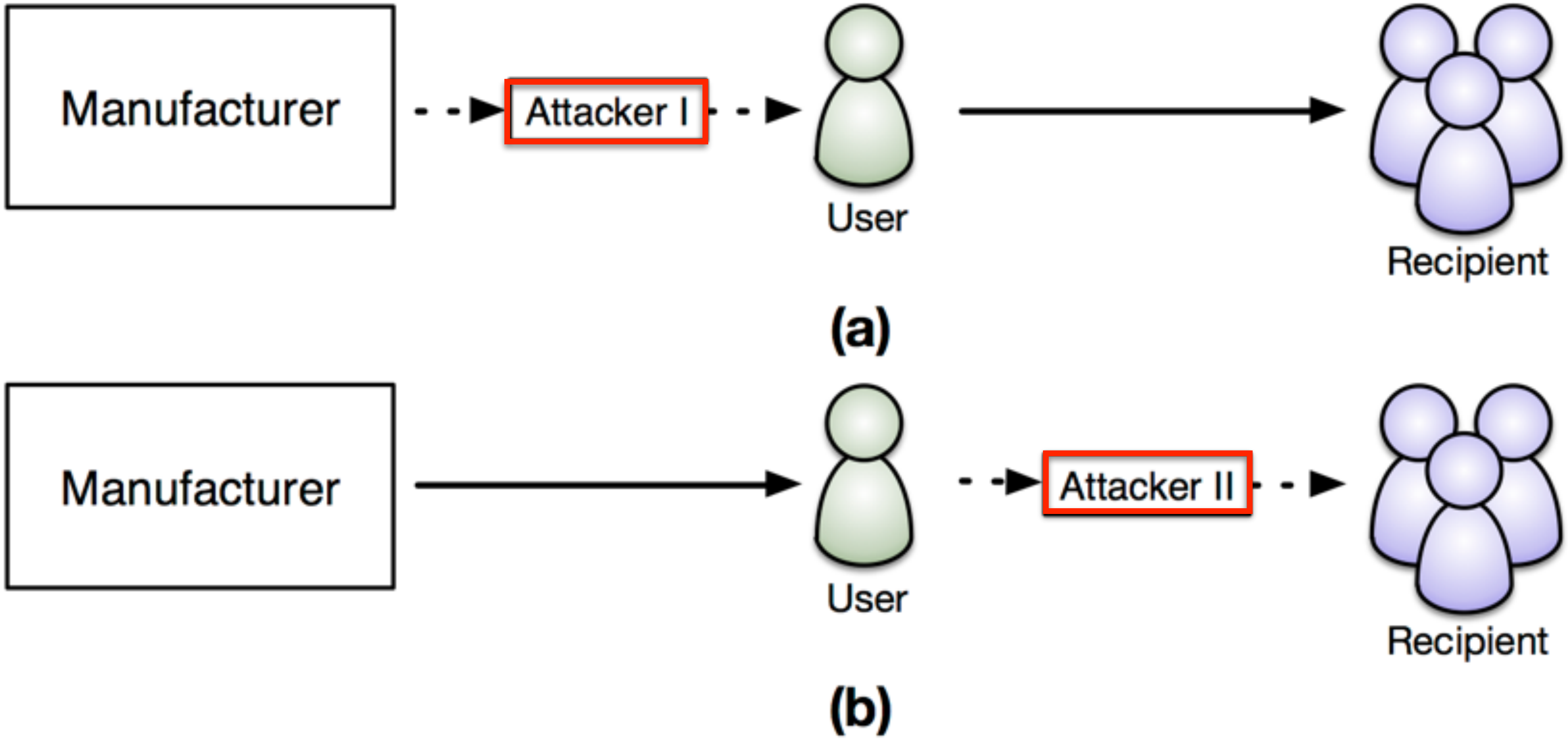

End to End Feasibility

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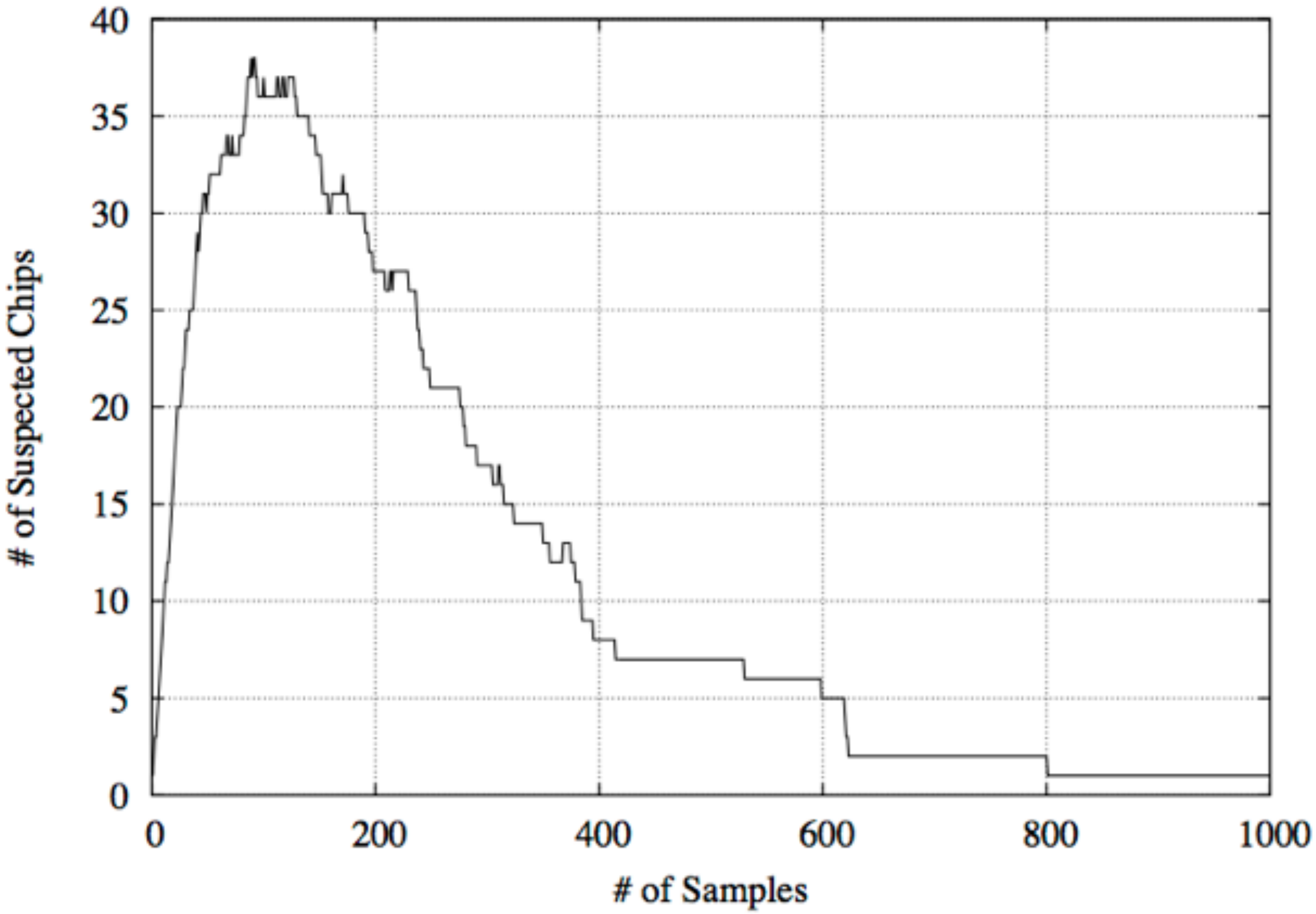

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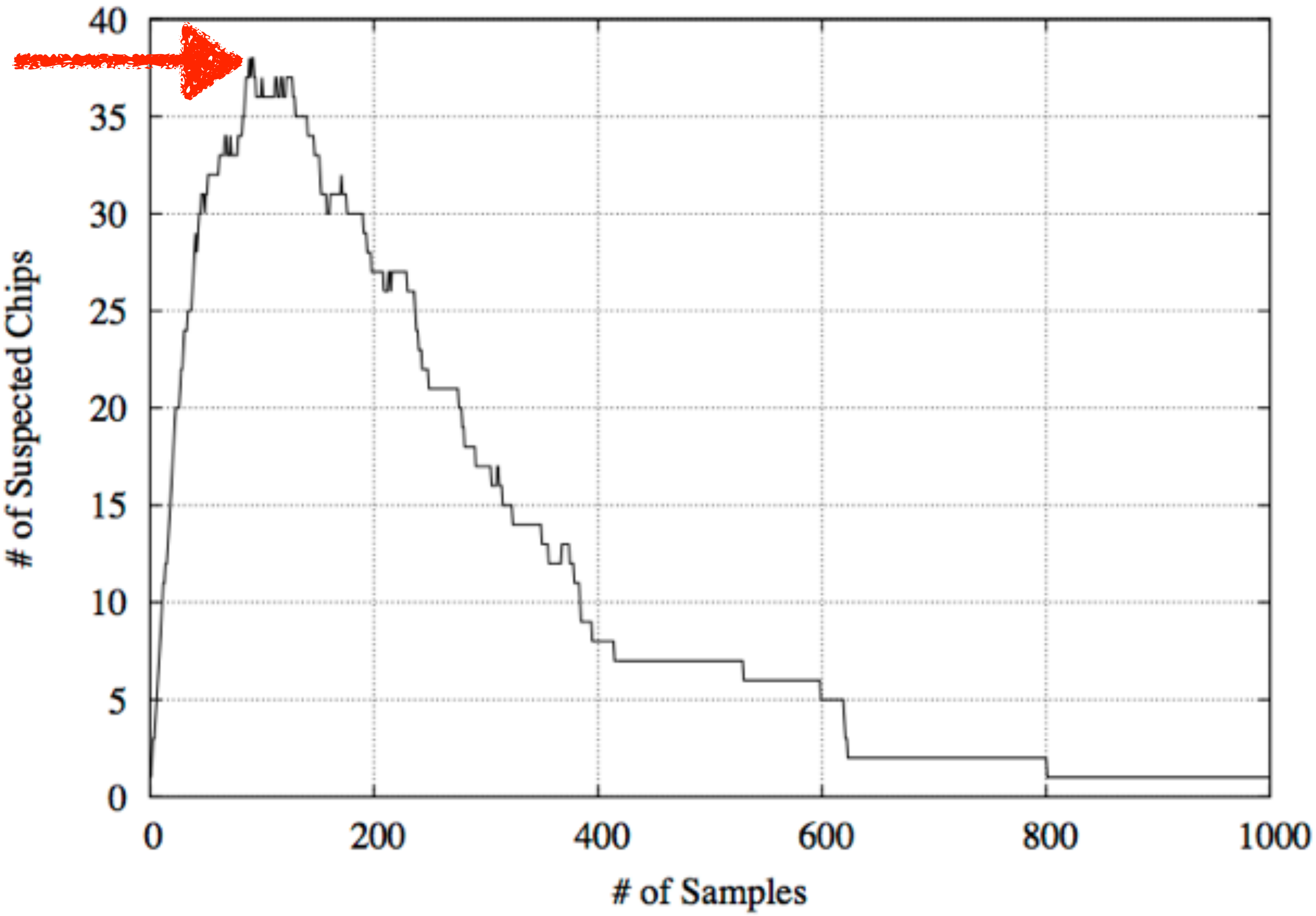

Chance of Mismatch

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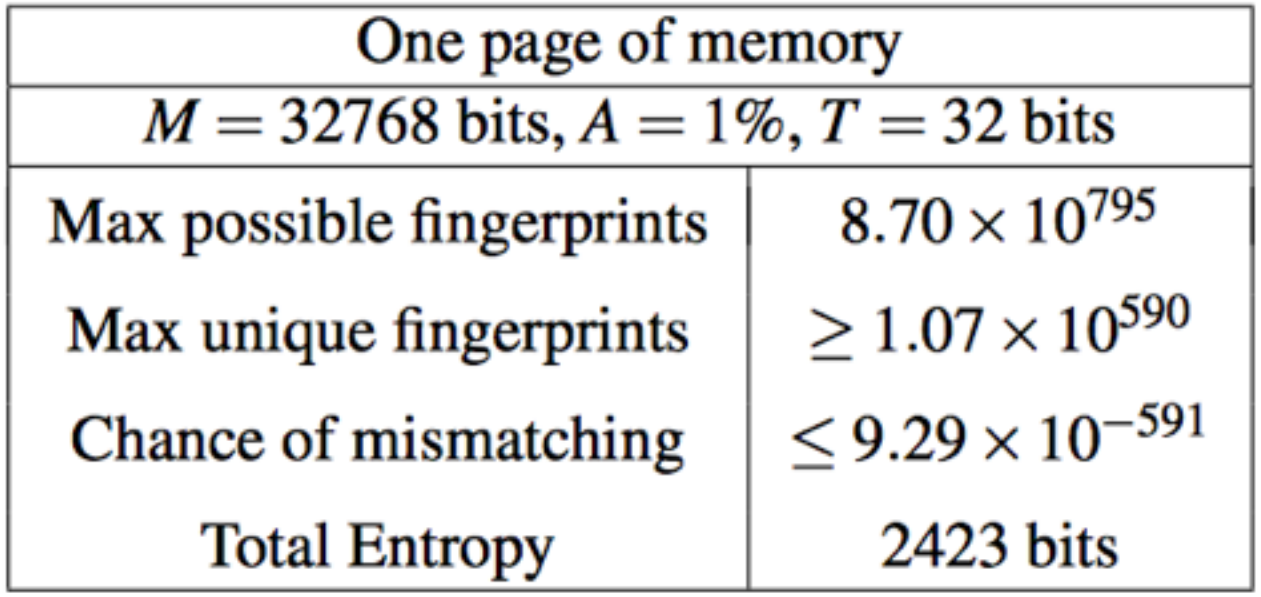
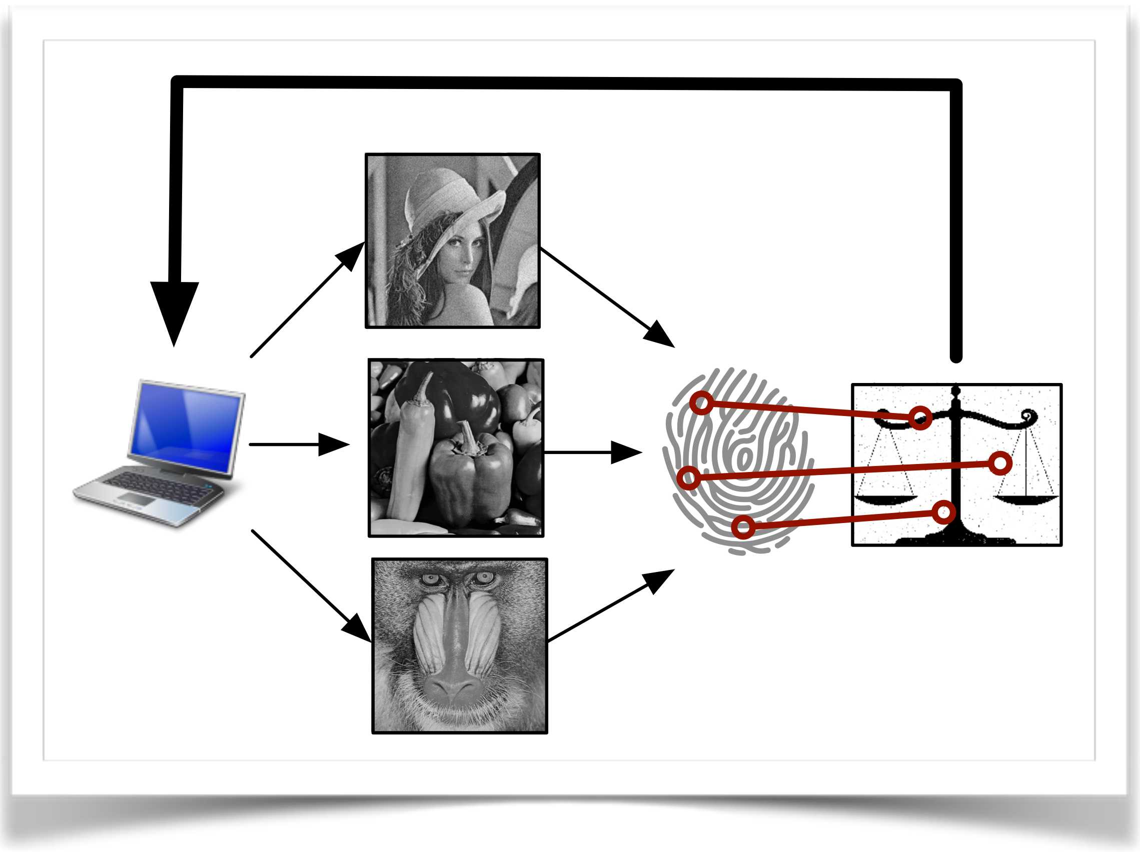


One page of memory	
$M = 32768$ bits, $A = 1\%$, $T = 32$ bits	
Max possible fingerprints	8.70×10^{795}
Max unique fingerprints	$\geq 1.07 \times 10^{590}$
Chance of mismatching	$\leq 9.29 \times 10^{-591}$
Total Entropy	2423 bits

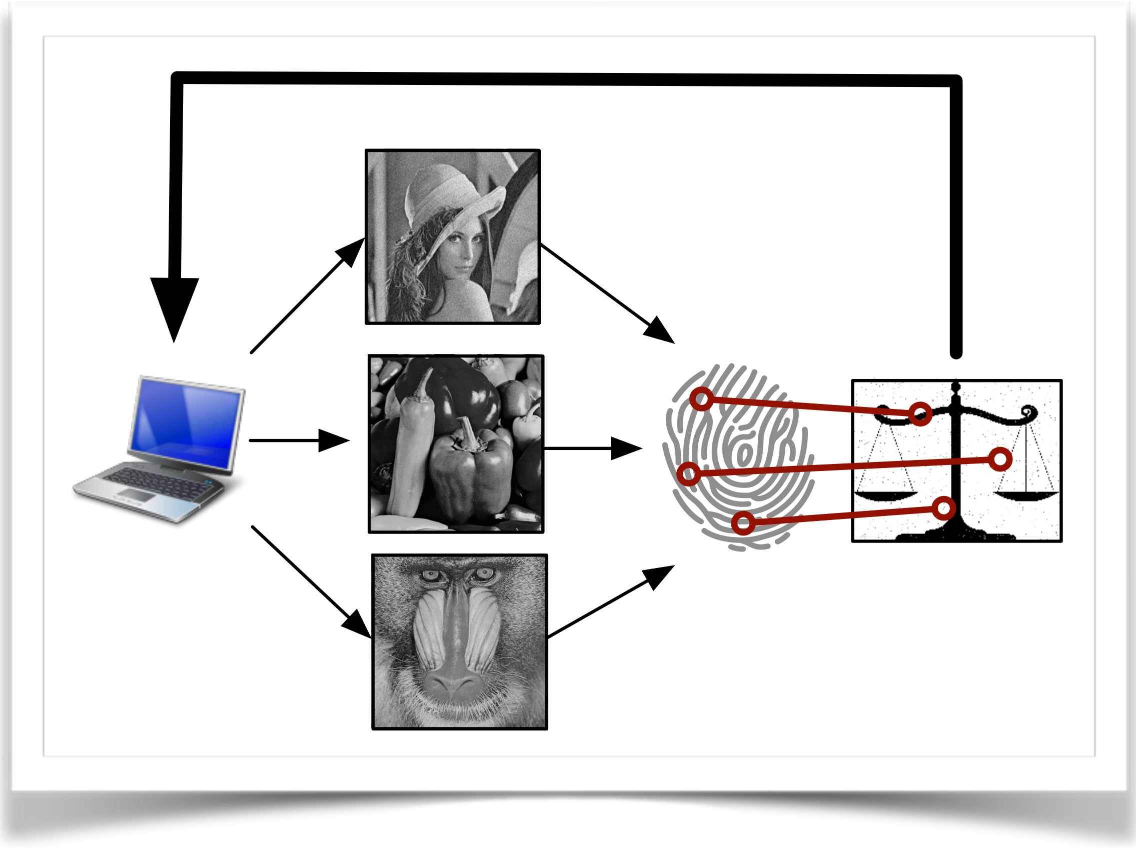
Conclusion



https://github.com/impedimentToProgress/ProbableCause

Conclusion

Consider **Security & Privacy** as a primary design criteria in emerging systems



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Backup Slides

Defenses

- Data Segregation
- Noise
- Data Scrambling

Error Localization

- Recalculate from known inputs
- Noise detection algorithms
- Speculative distance calculation

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