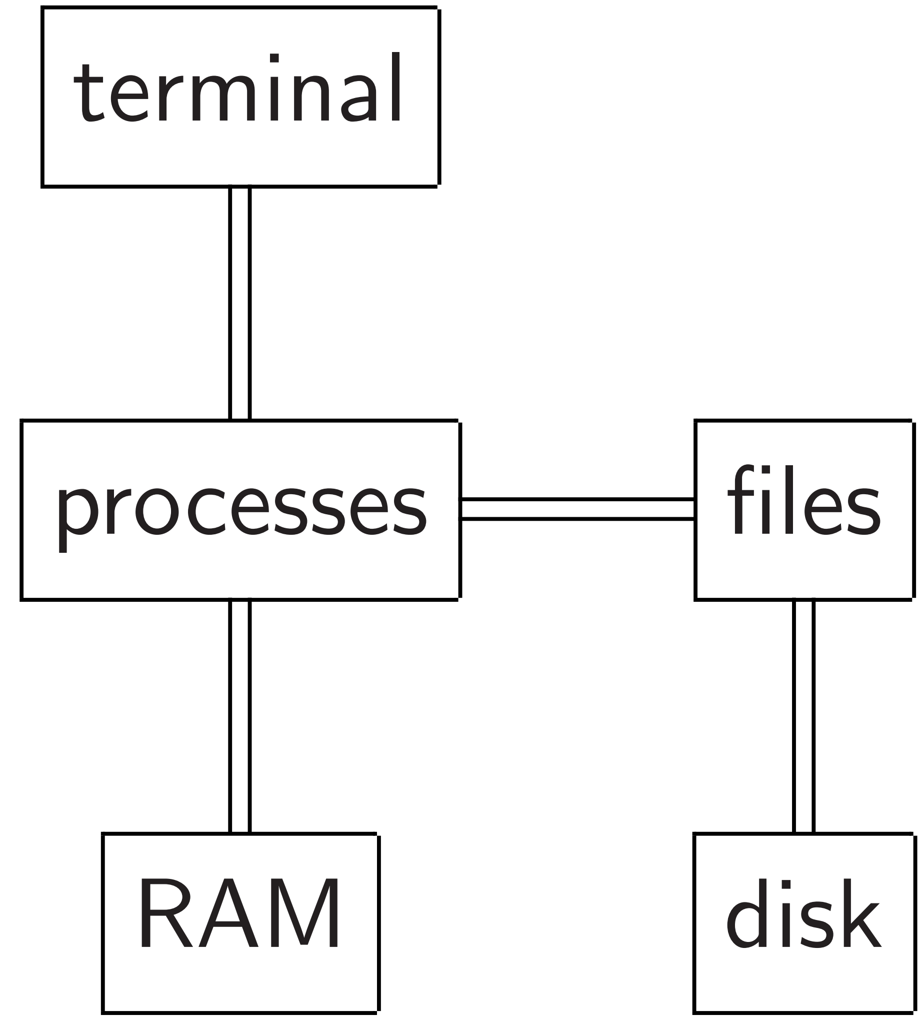
Usable verification of fast cryptographic software

Daniel J. Bernstein

University of Illinois at Chicago &
Technische Universiteit Eindhoven



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Provides convenient functions
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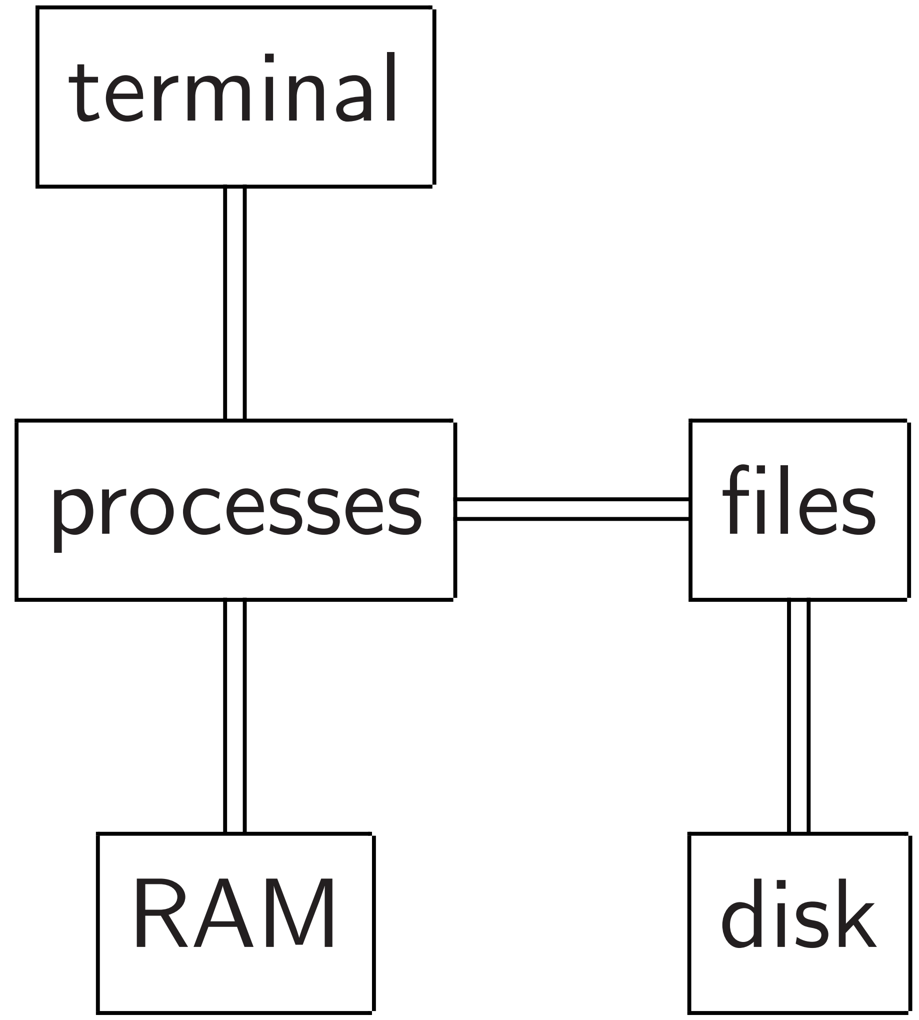

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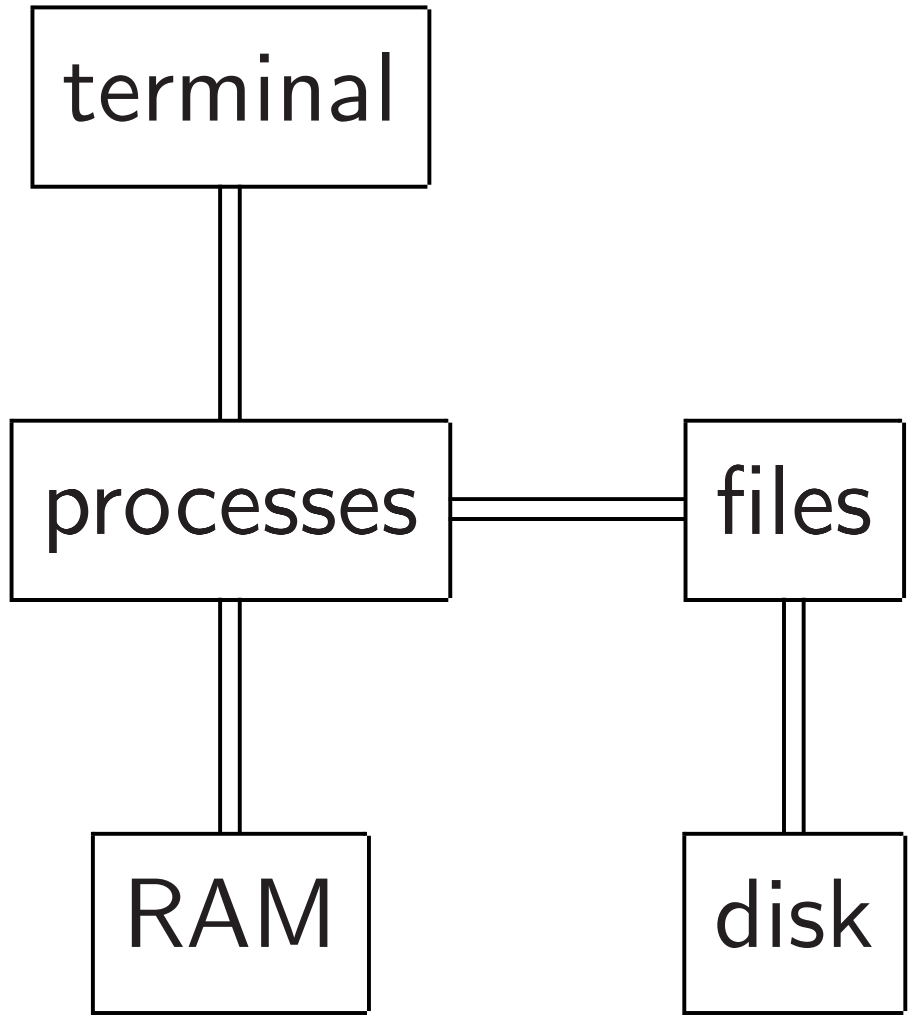

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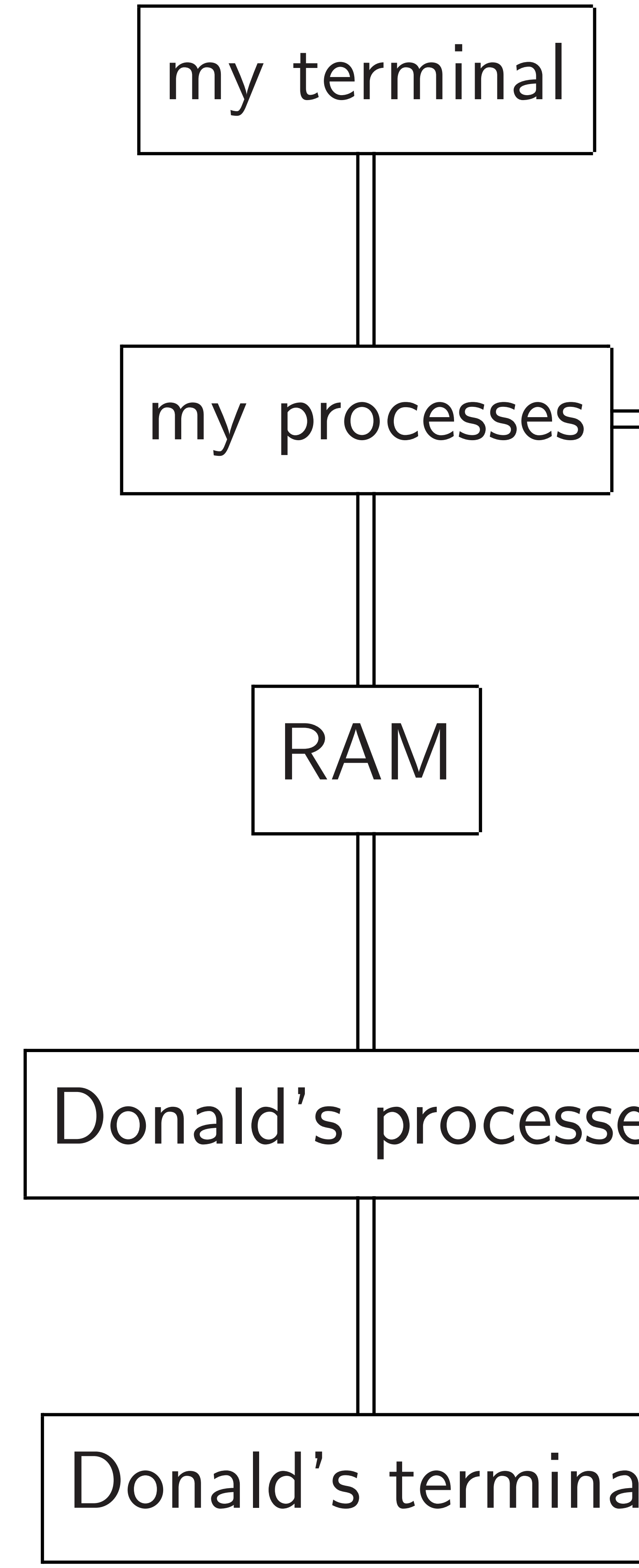

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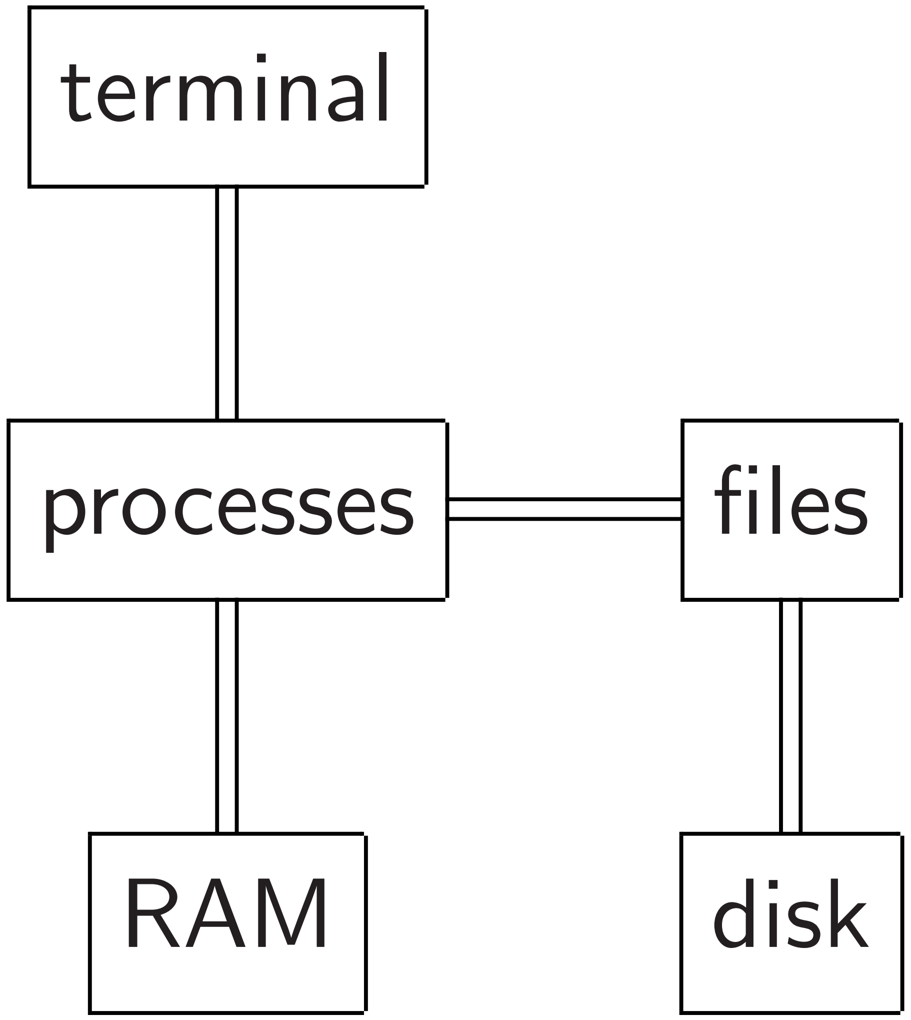

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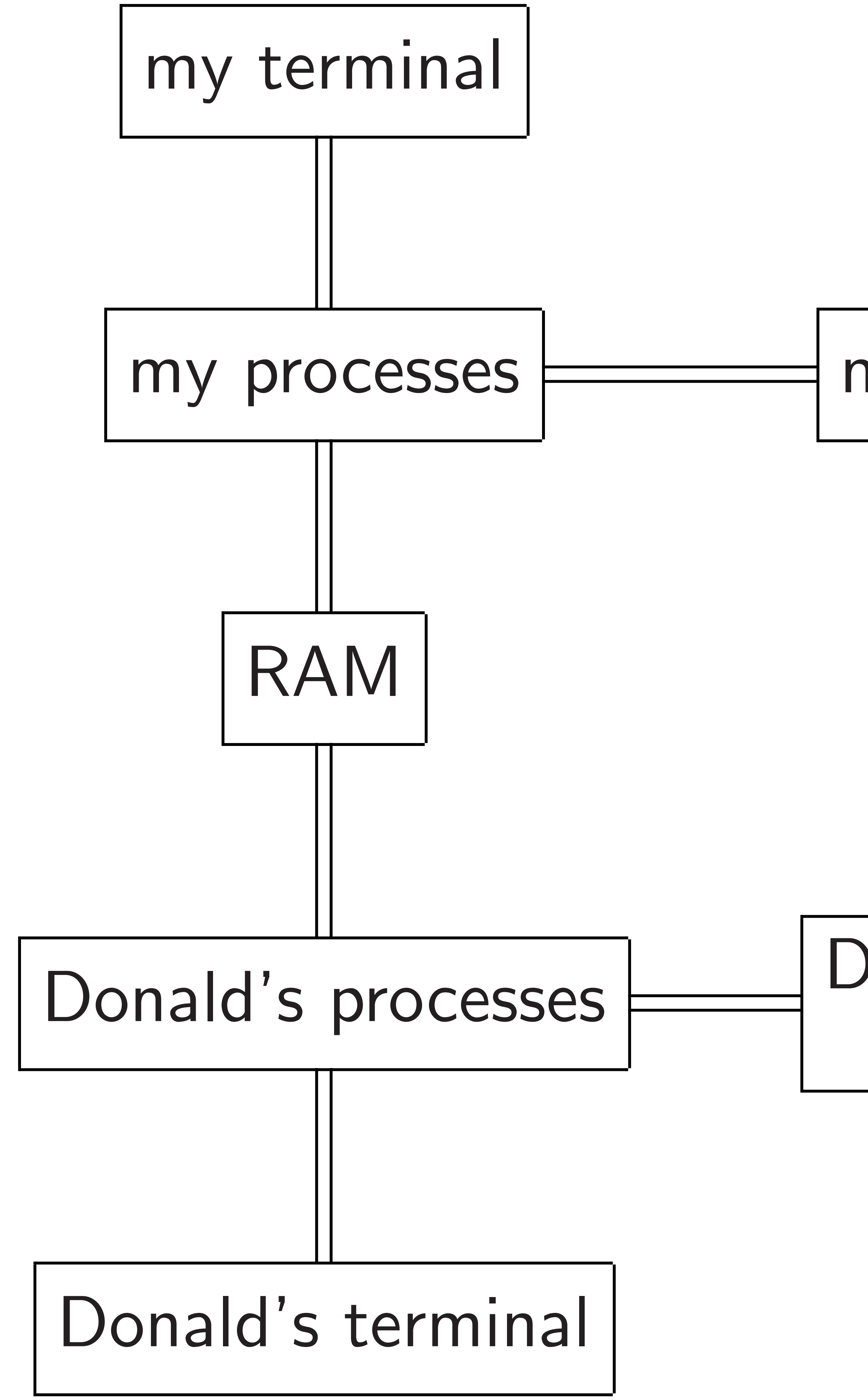

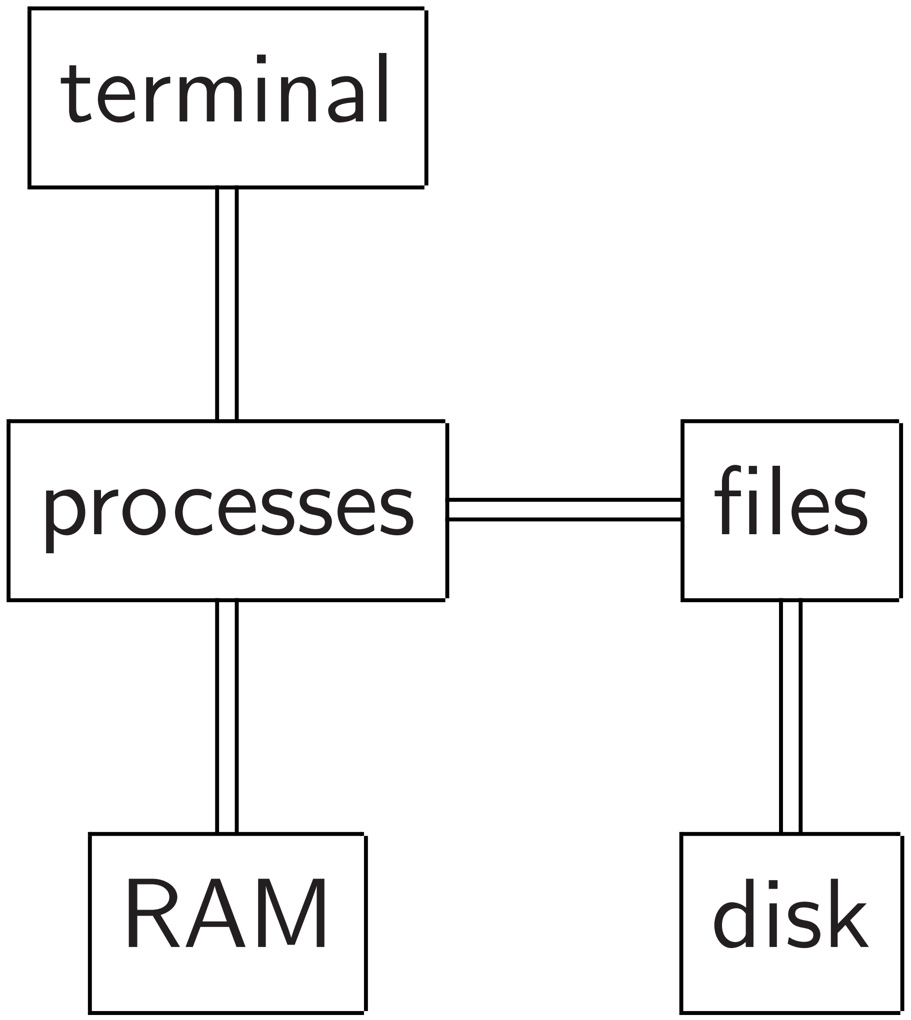

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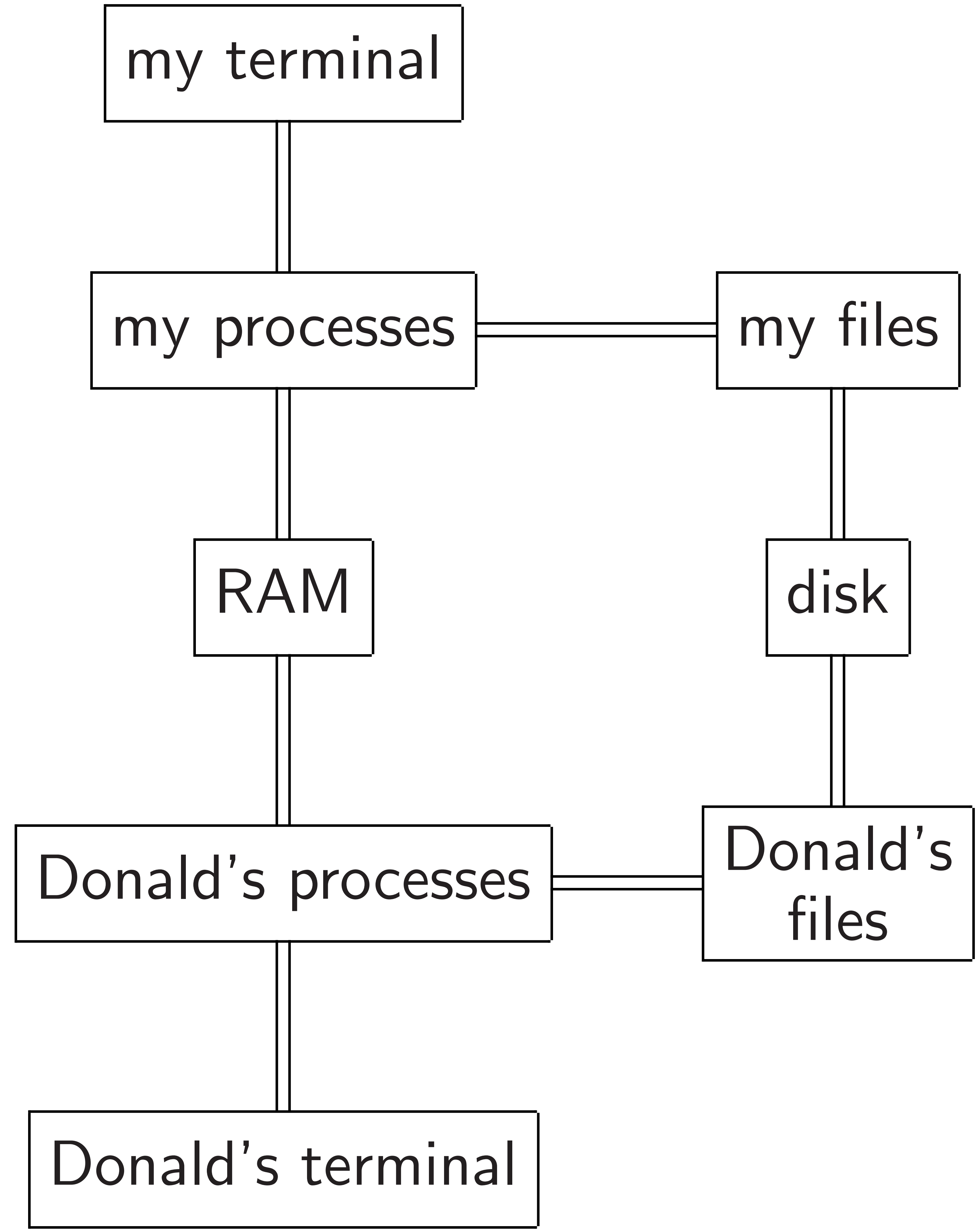

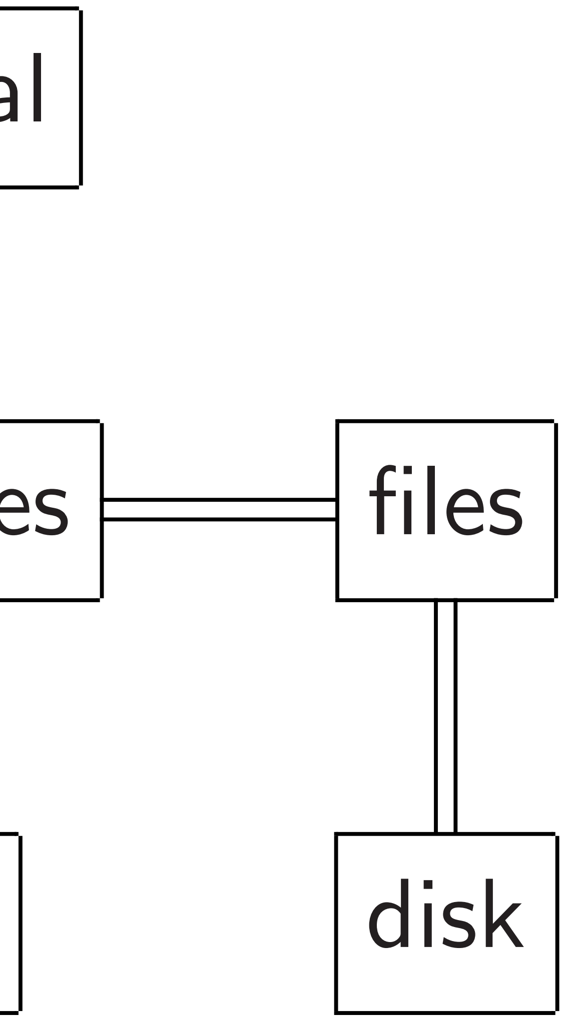

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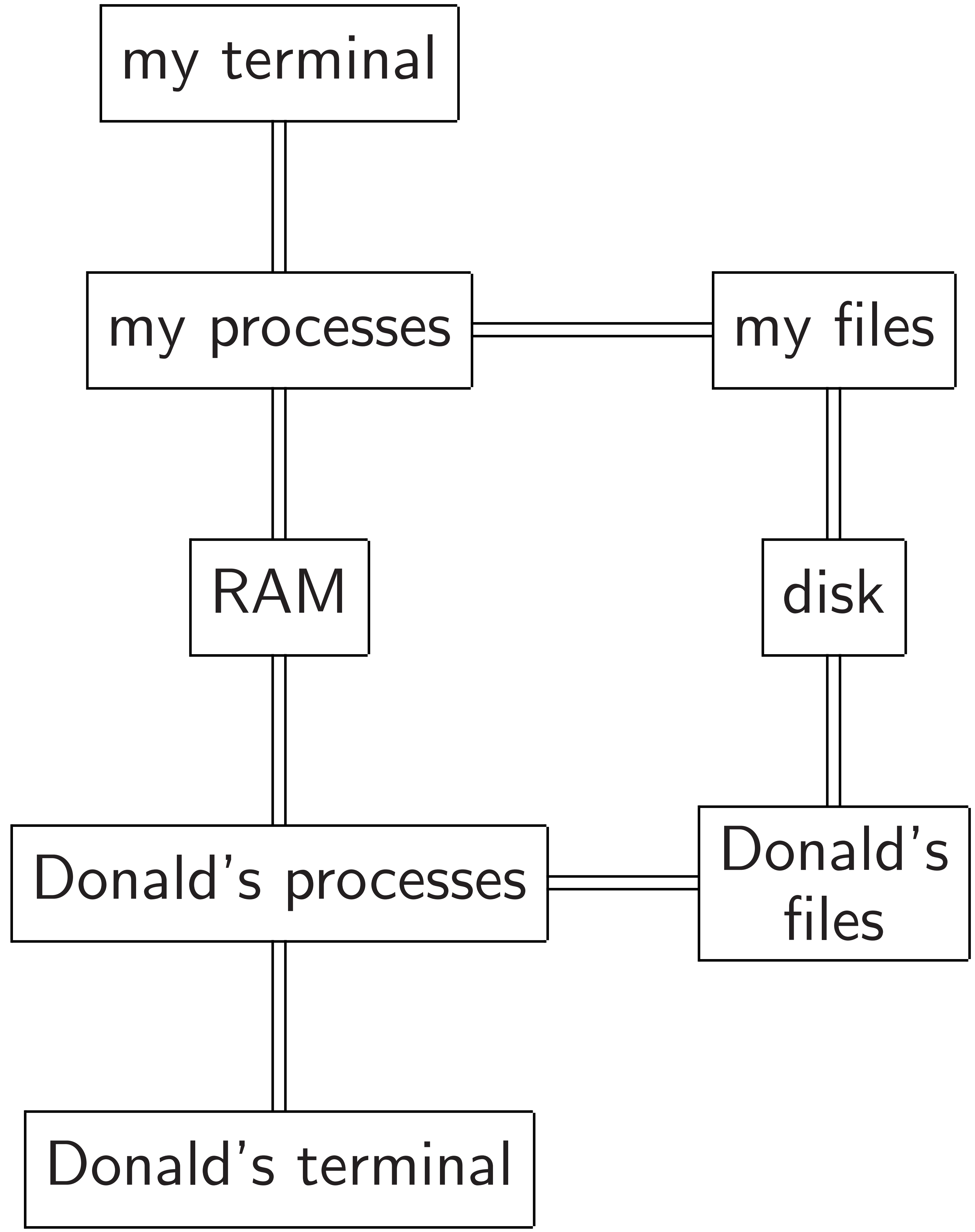

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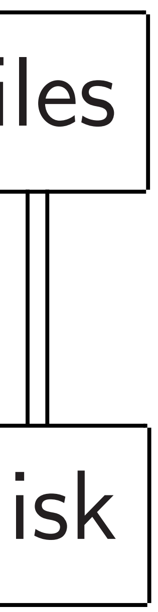

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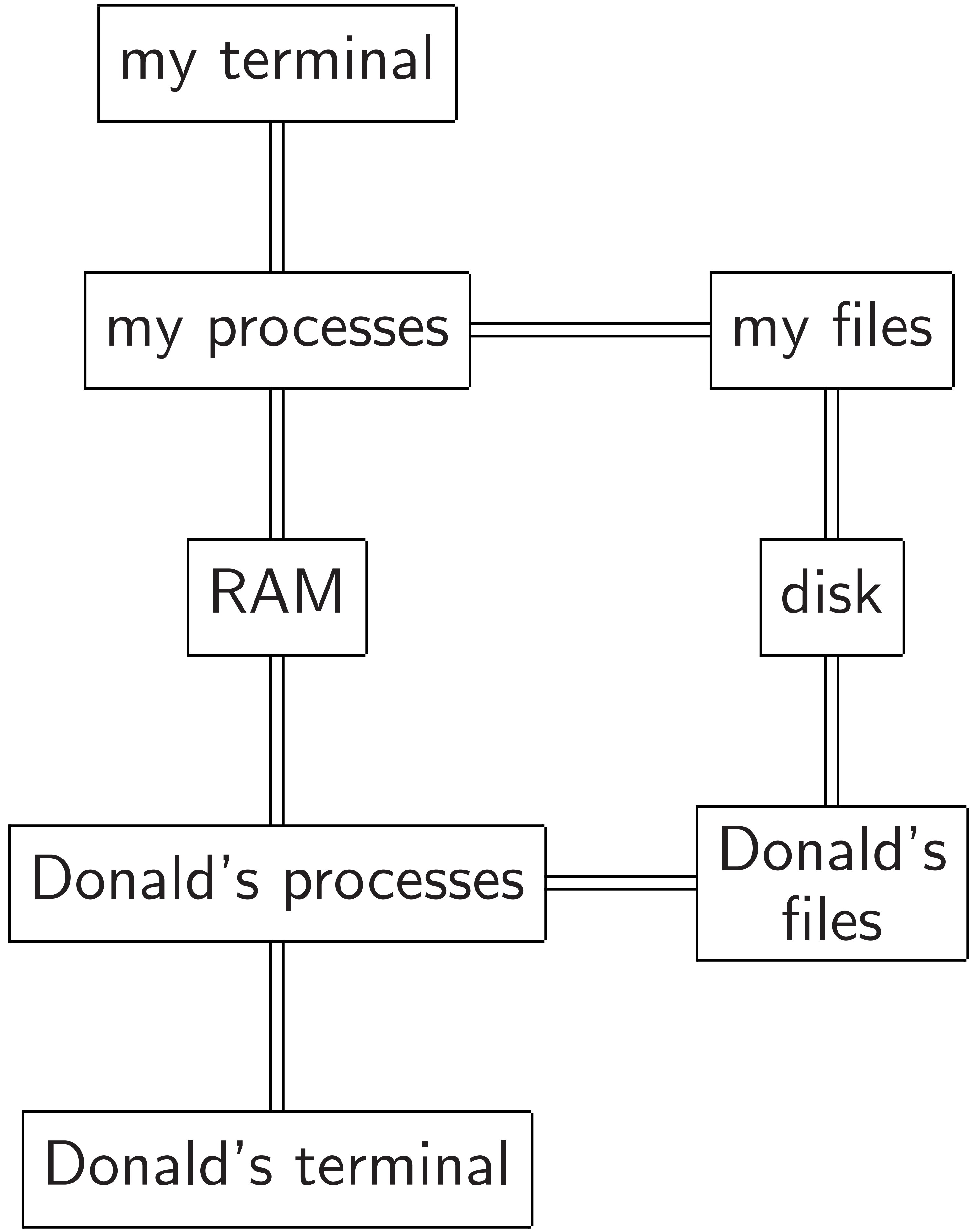

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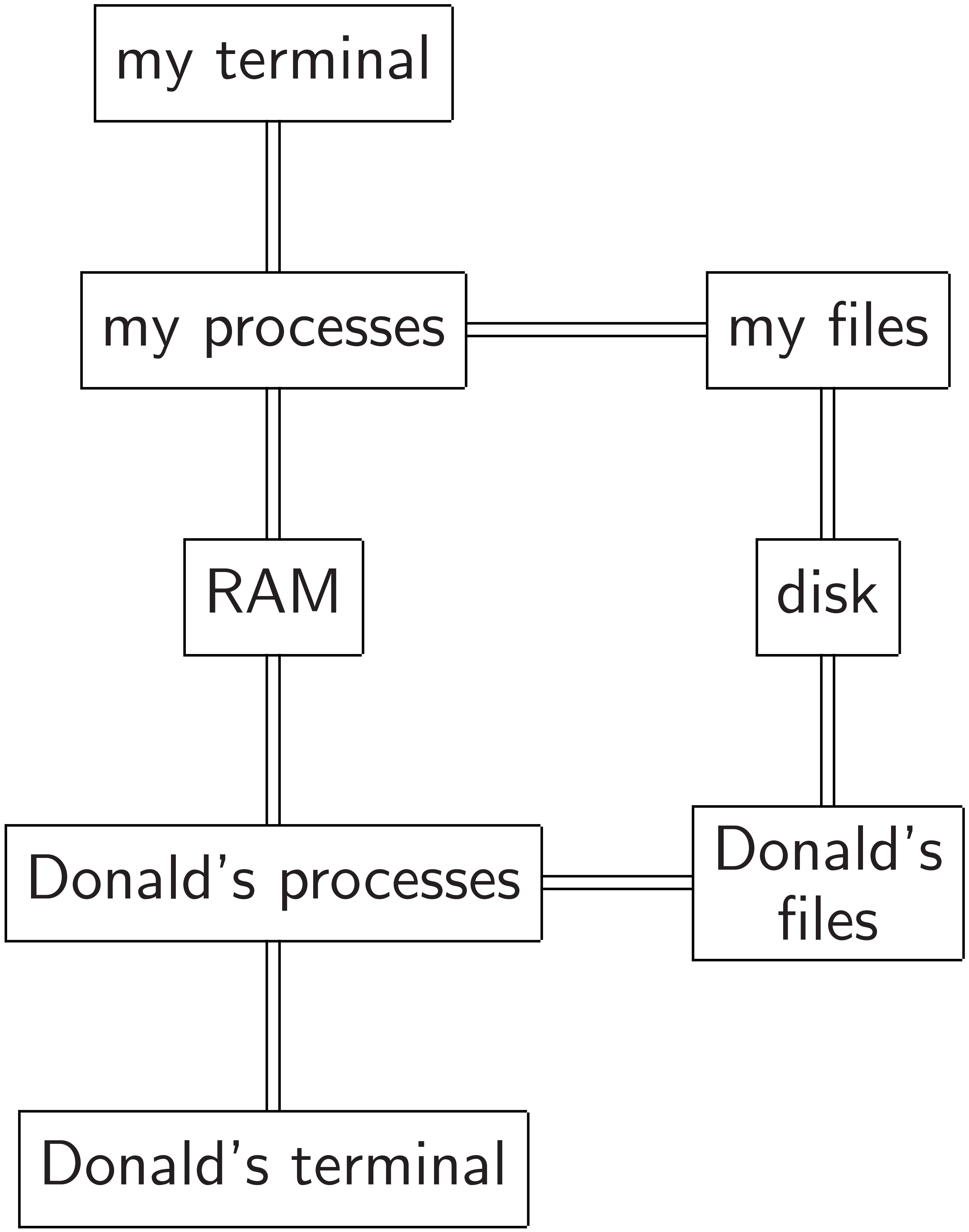

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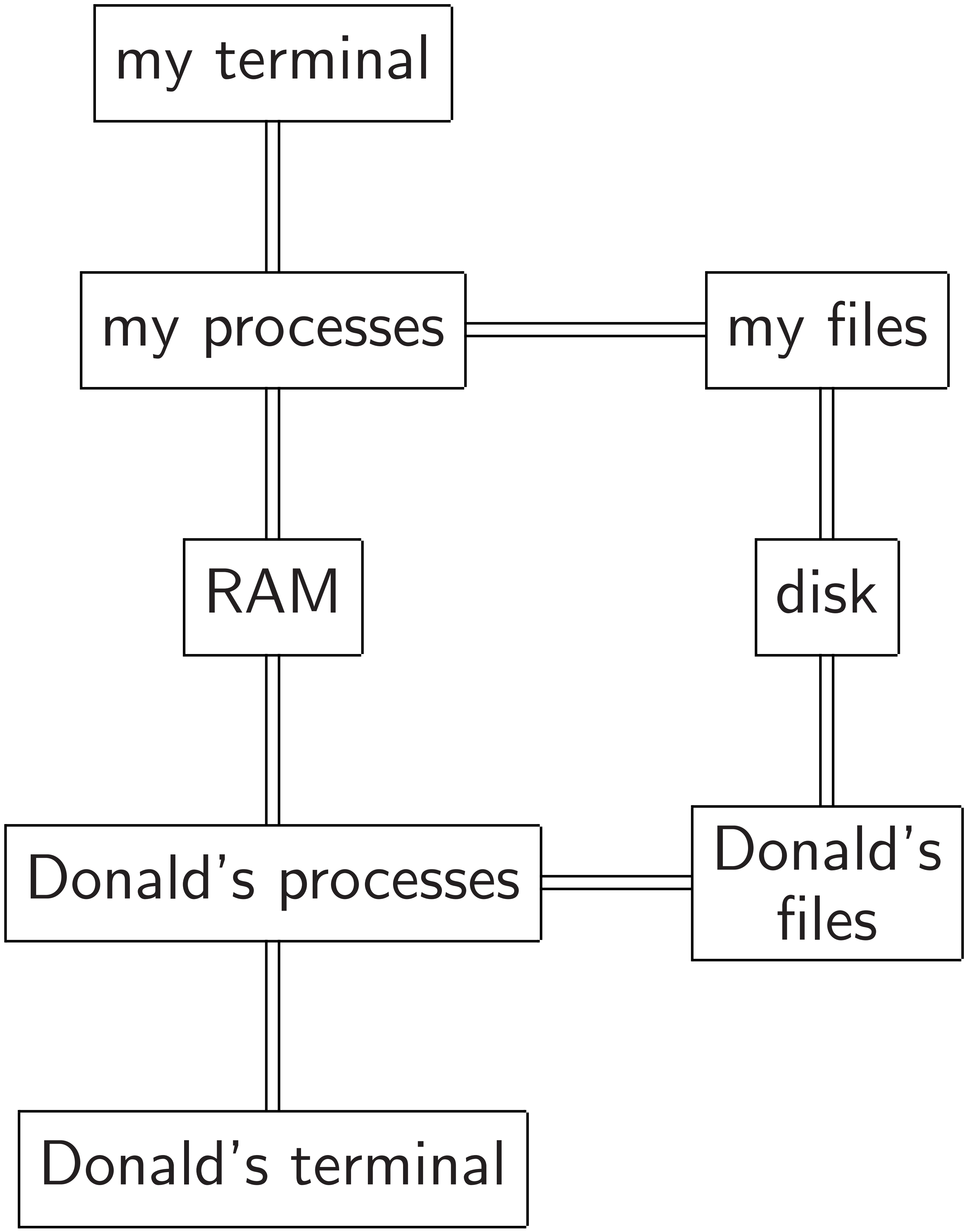

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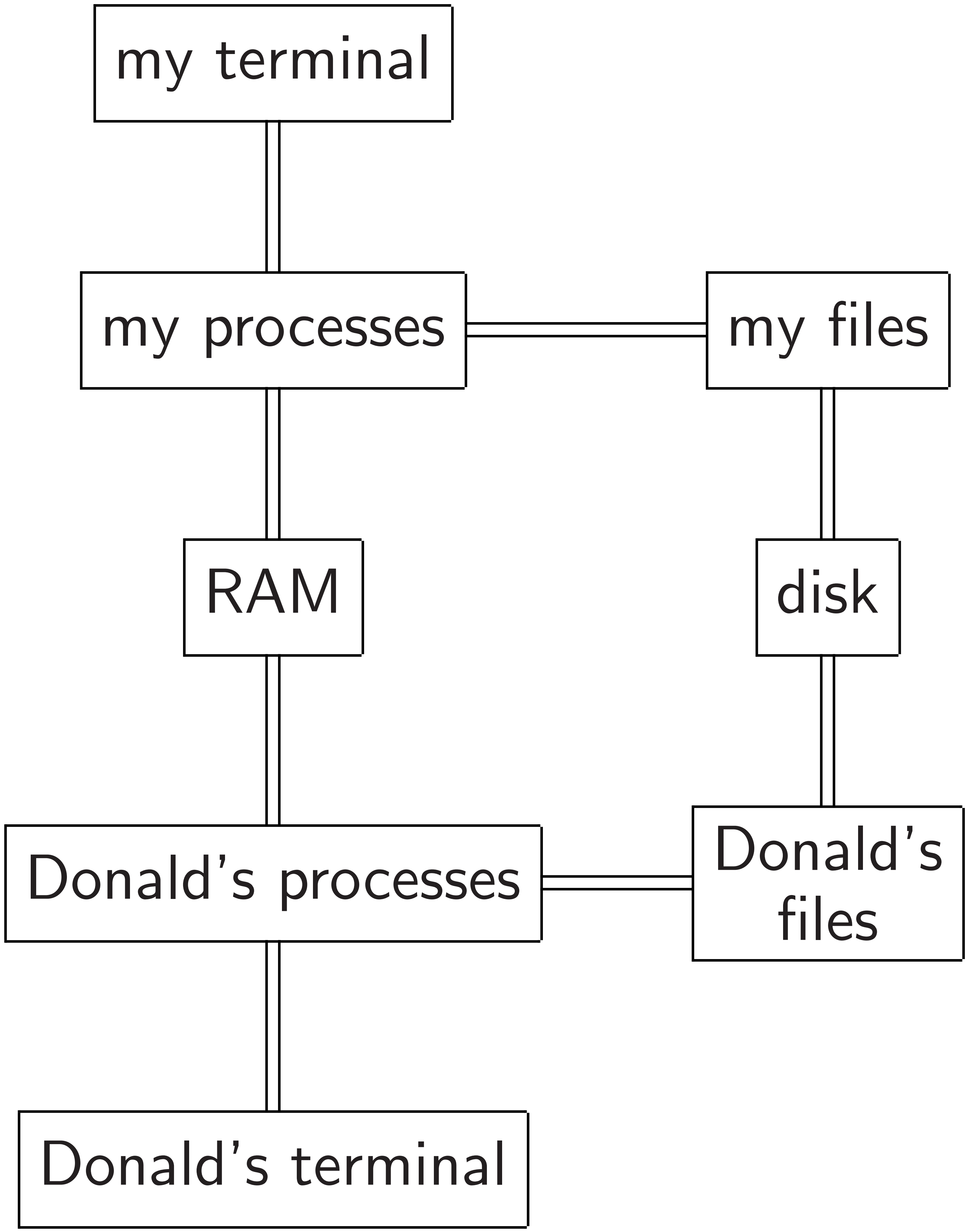

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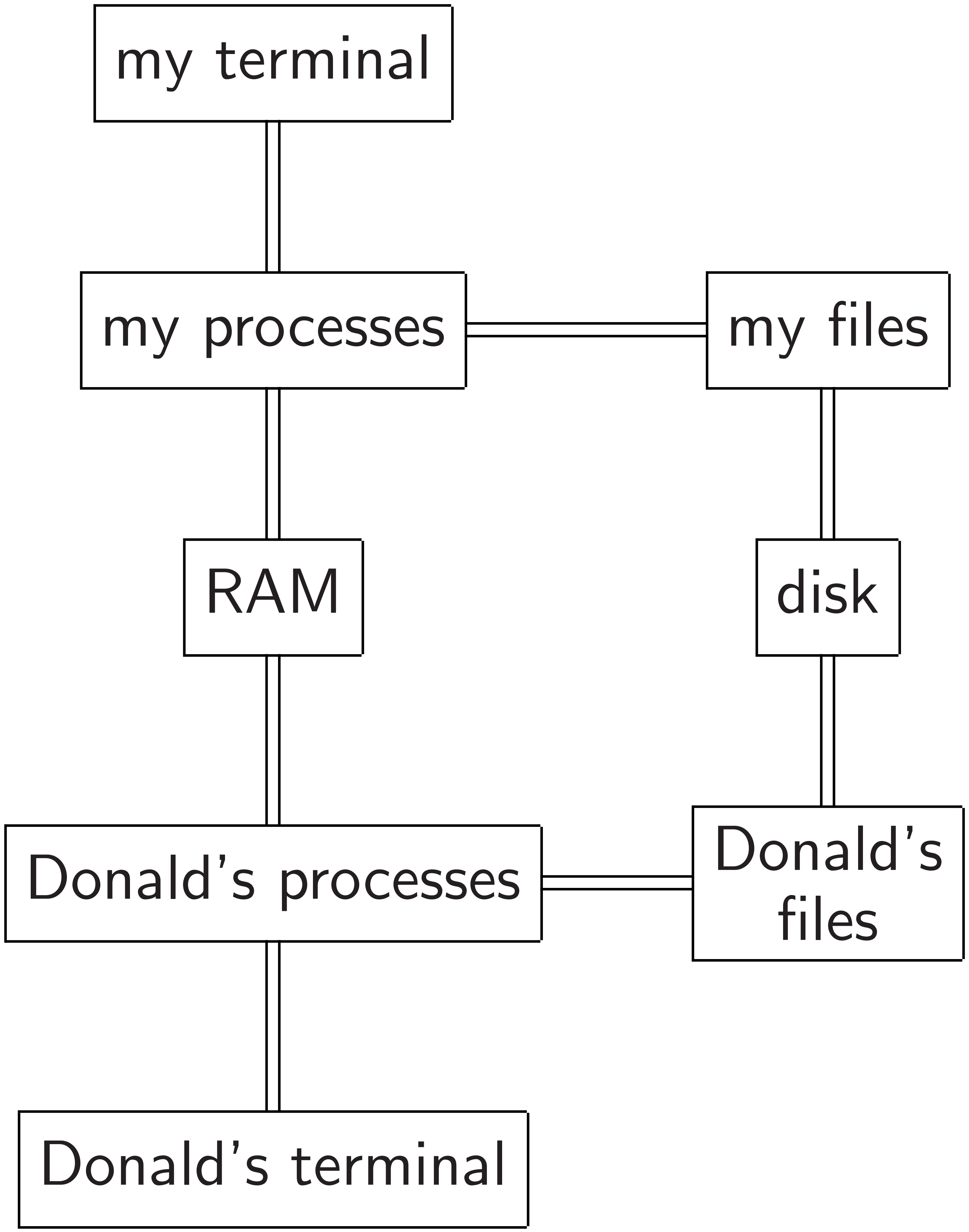

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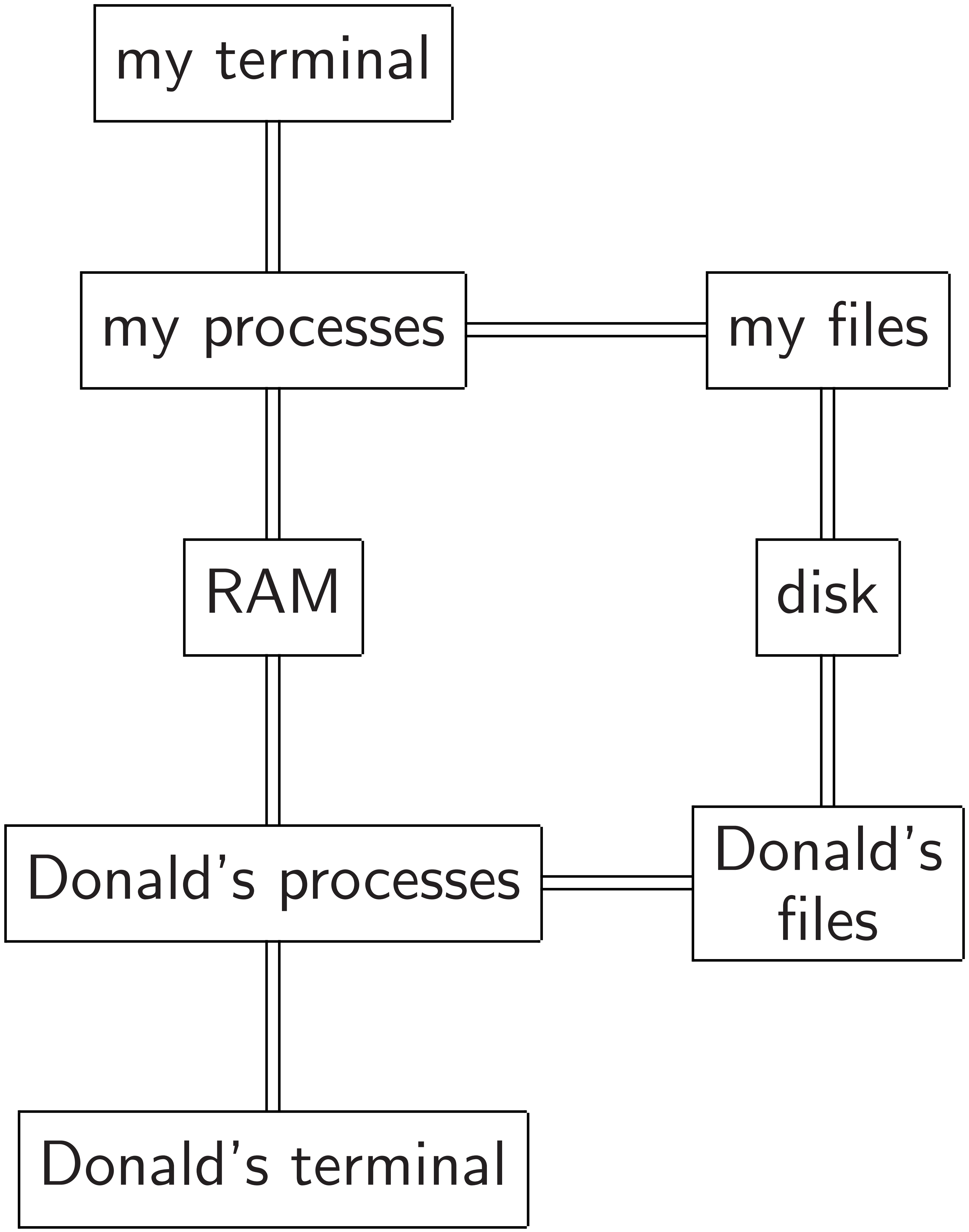
Defense: I have a high-entropy randomly generated password.



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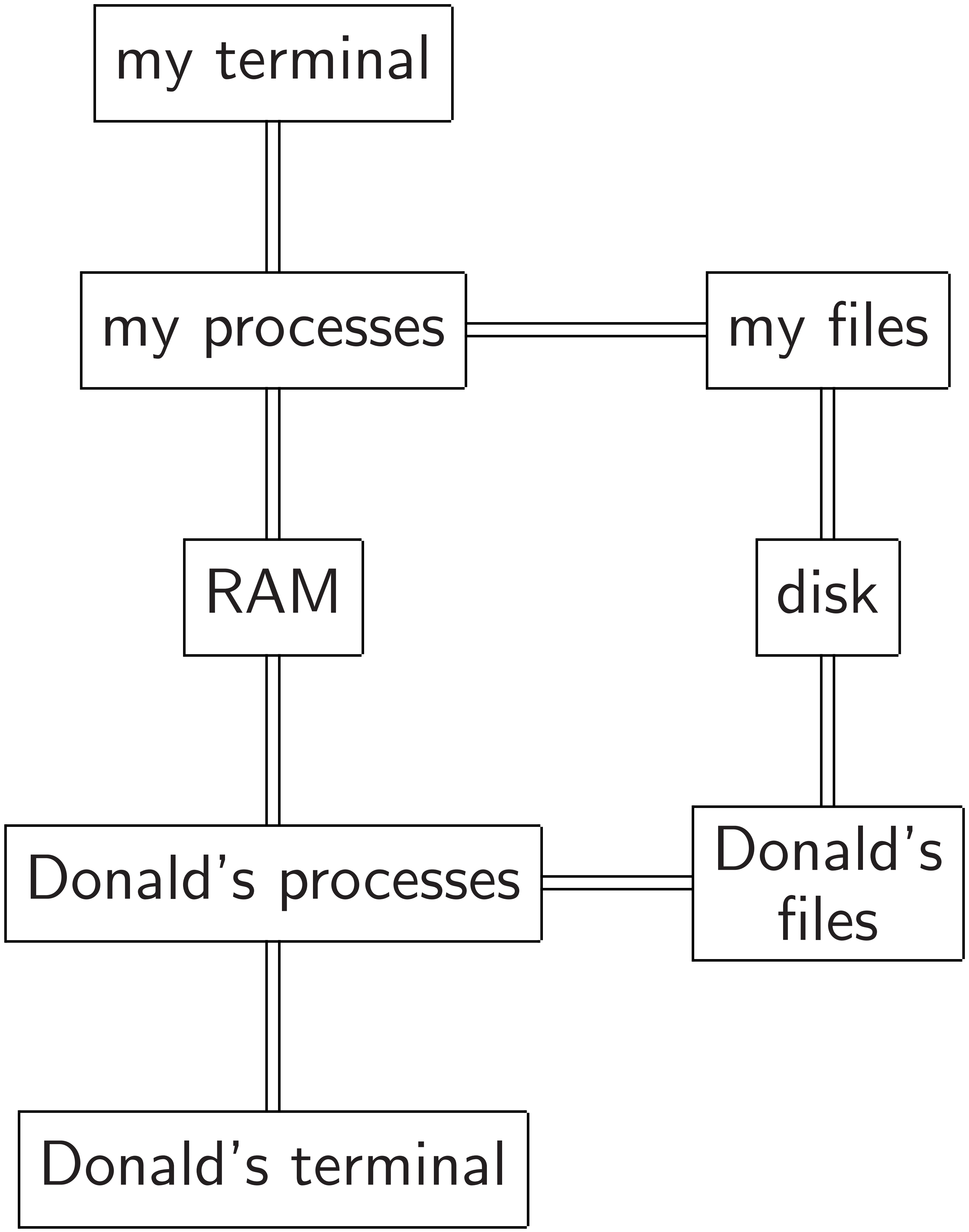

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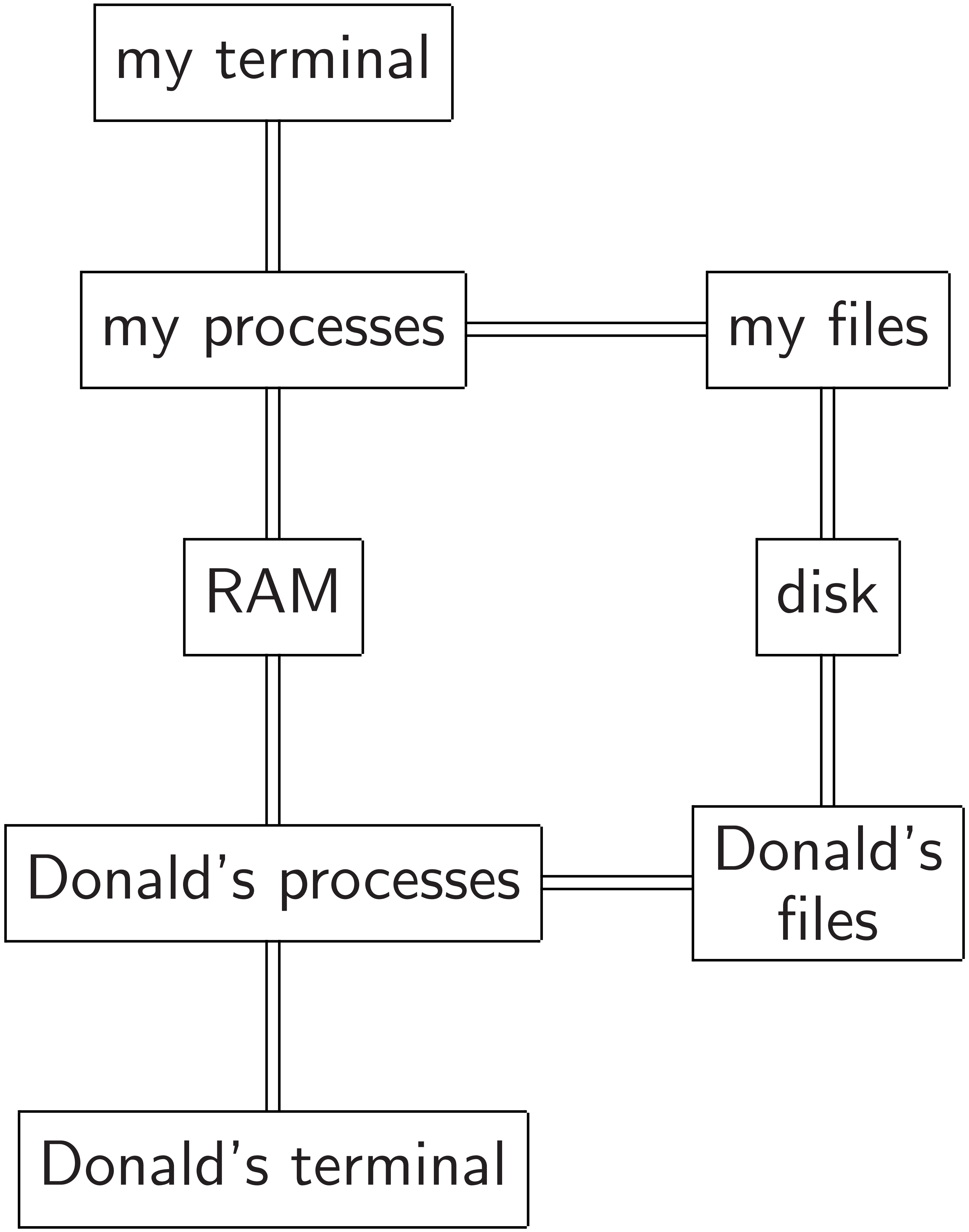

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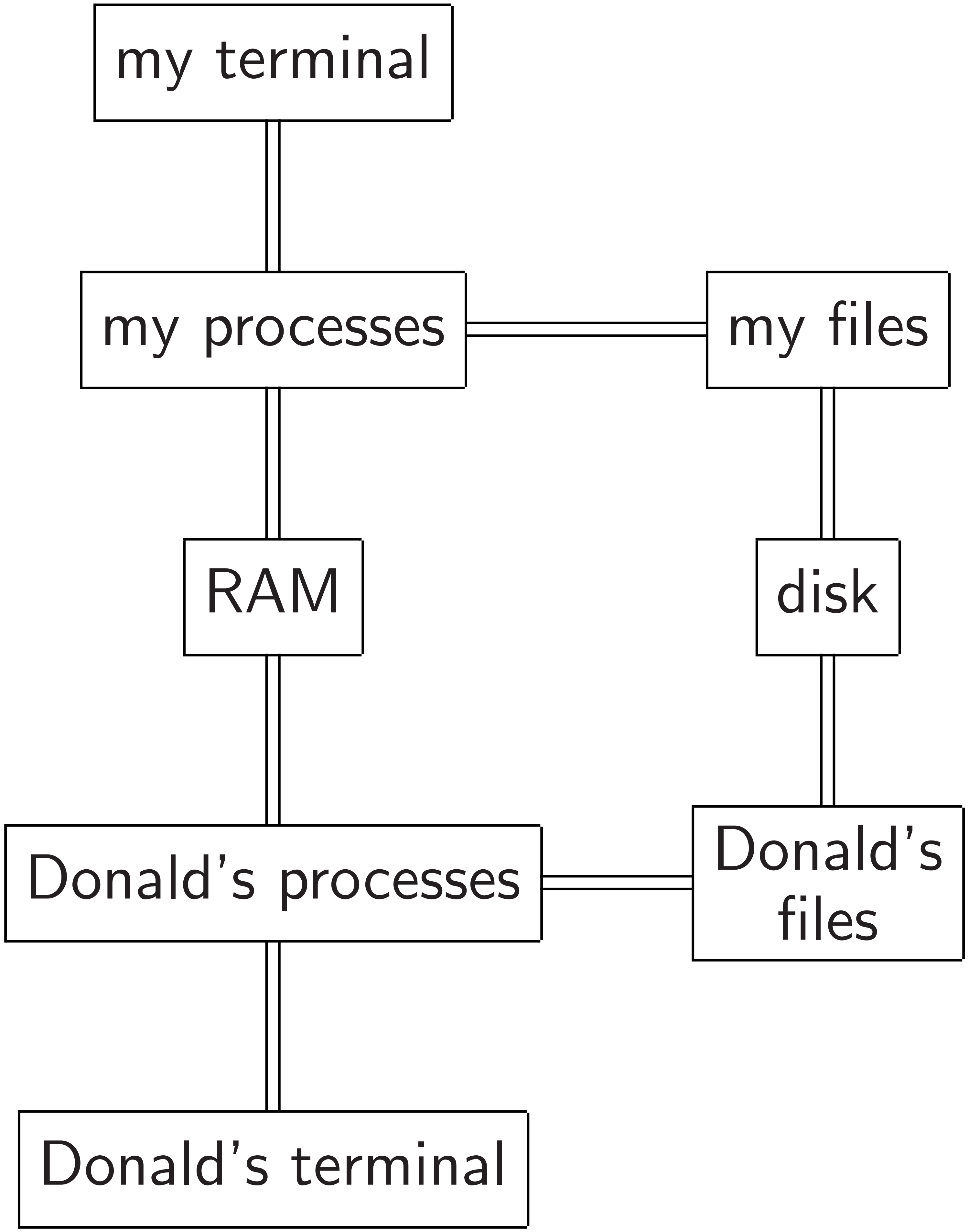

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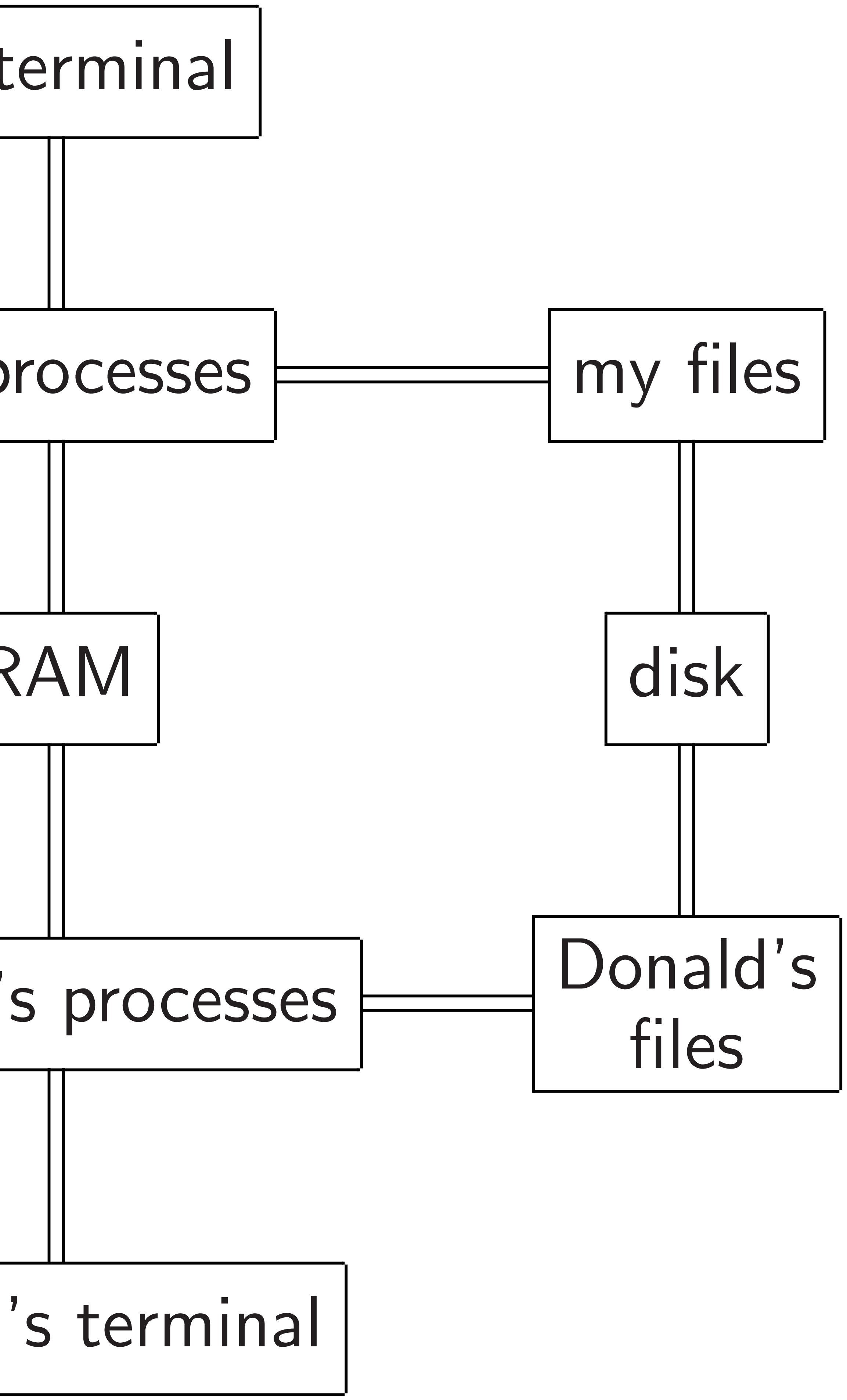

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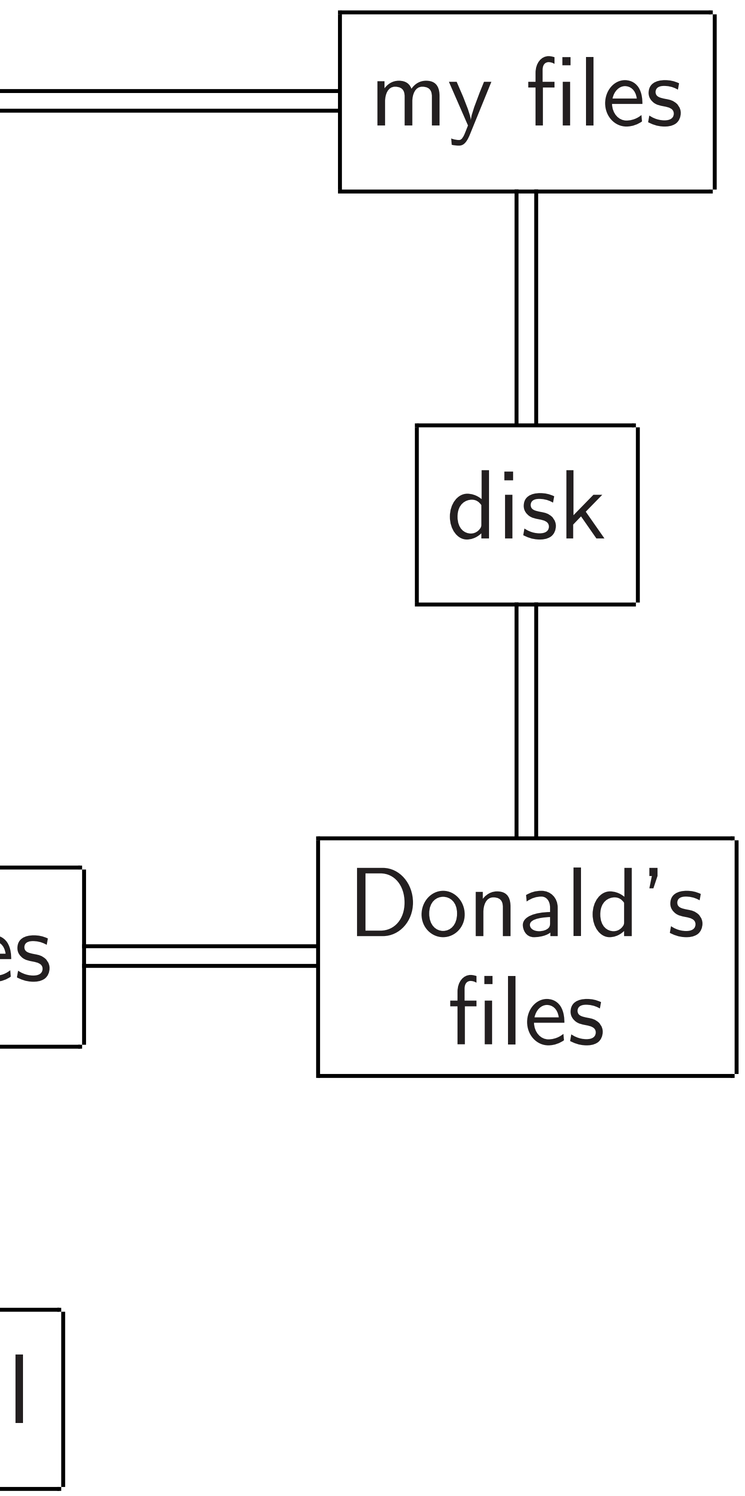

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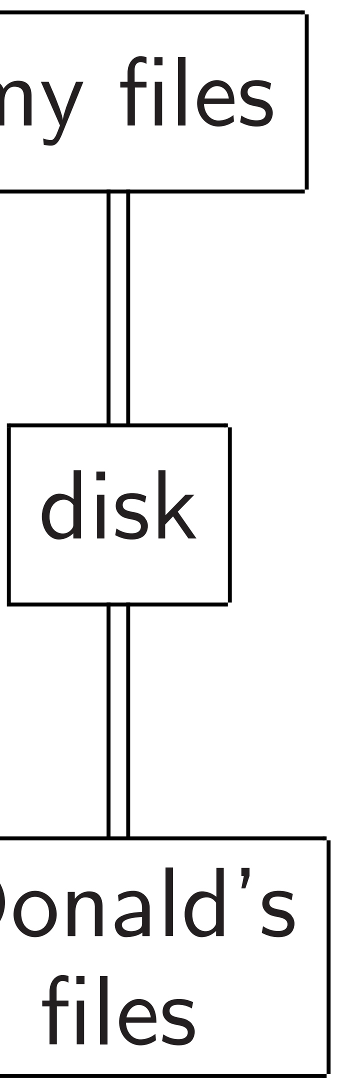

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Two-part defense:

1. "Memory protection". Hardware does not allow processes to access data outside areas marked by kernel.

2. Kernel keeps track of which parts of RAM and disk are mine, and which parts are Donald's.

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Successful example: computer-verified proof of seL4 microkernel correctness, including RAM partitioning etc.

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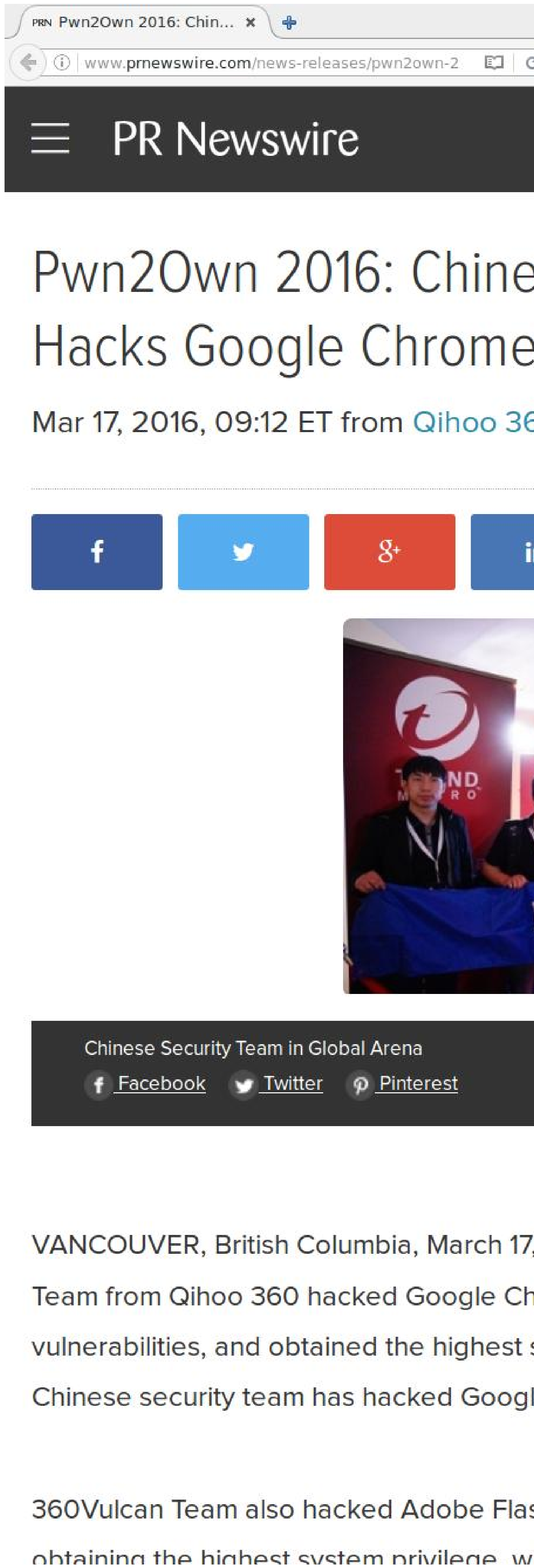

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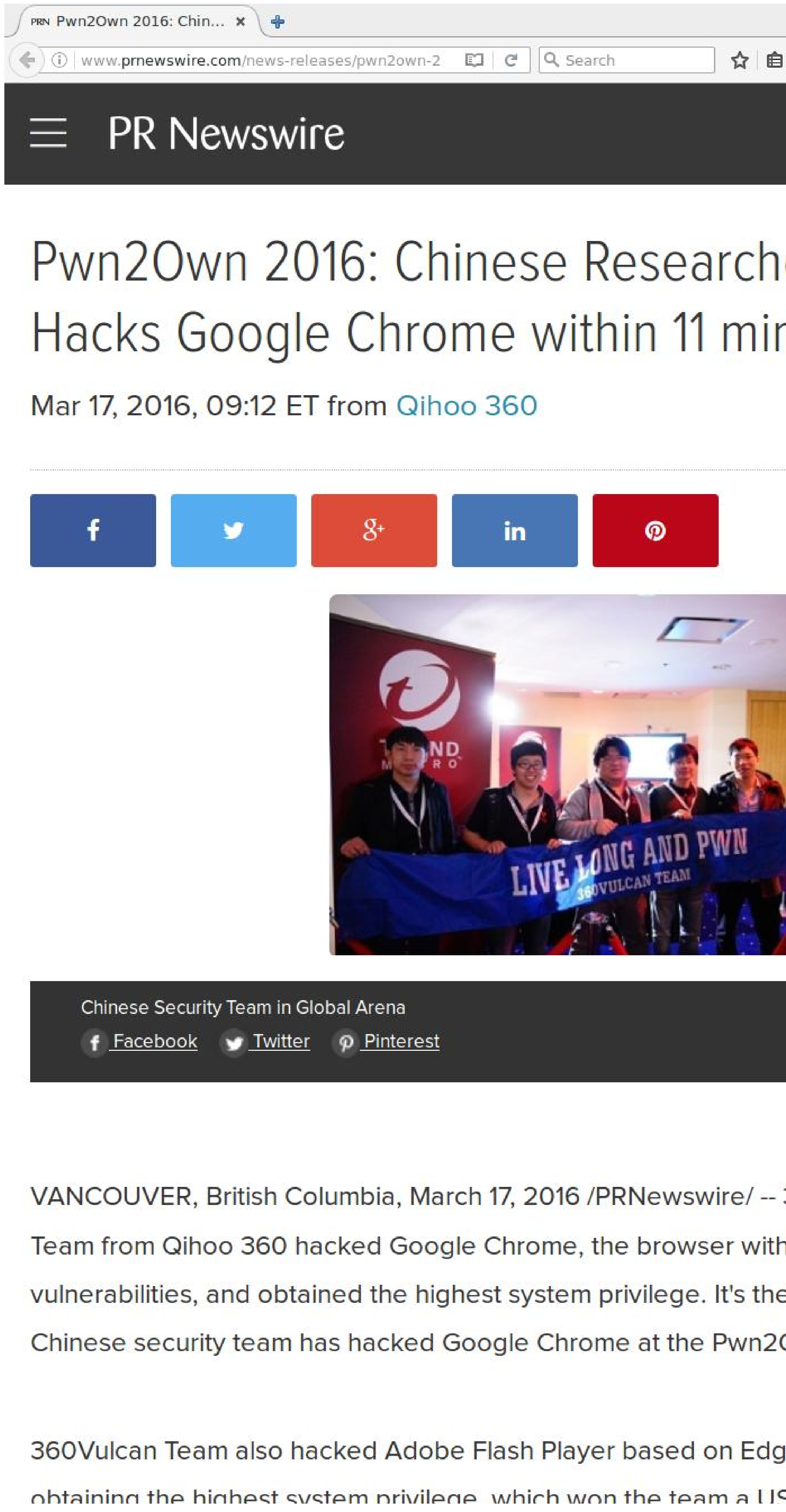
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Pwn2Own 2016: Chinese Research
Hacks Google Chrome within 11 mir

Mar 17, 2016, 09:12 ET from Qihoo 360

Chinese Security Team in Global Arena
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VANCOUVER, British Columbia, March 17, 2016 /PRNewswire/ --
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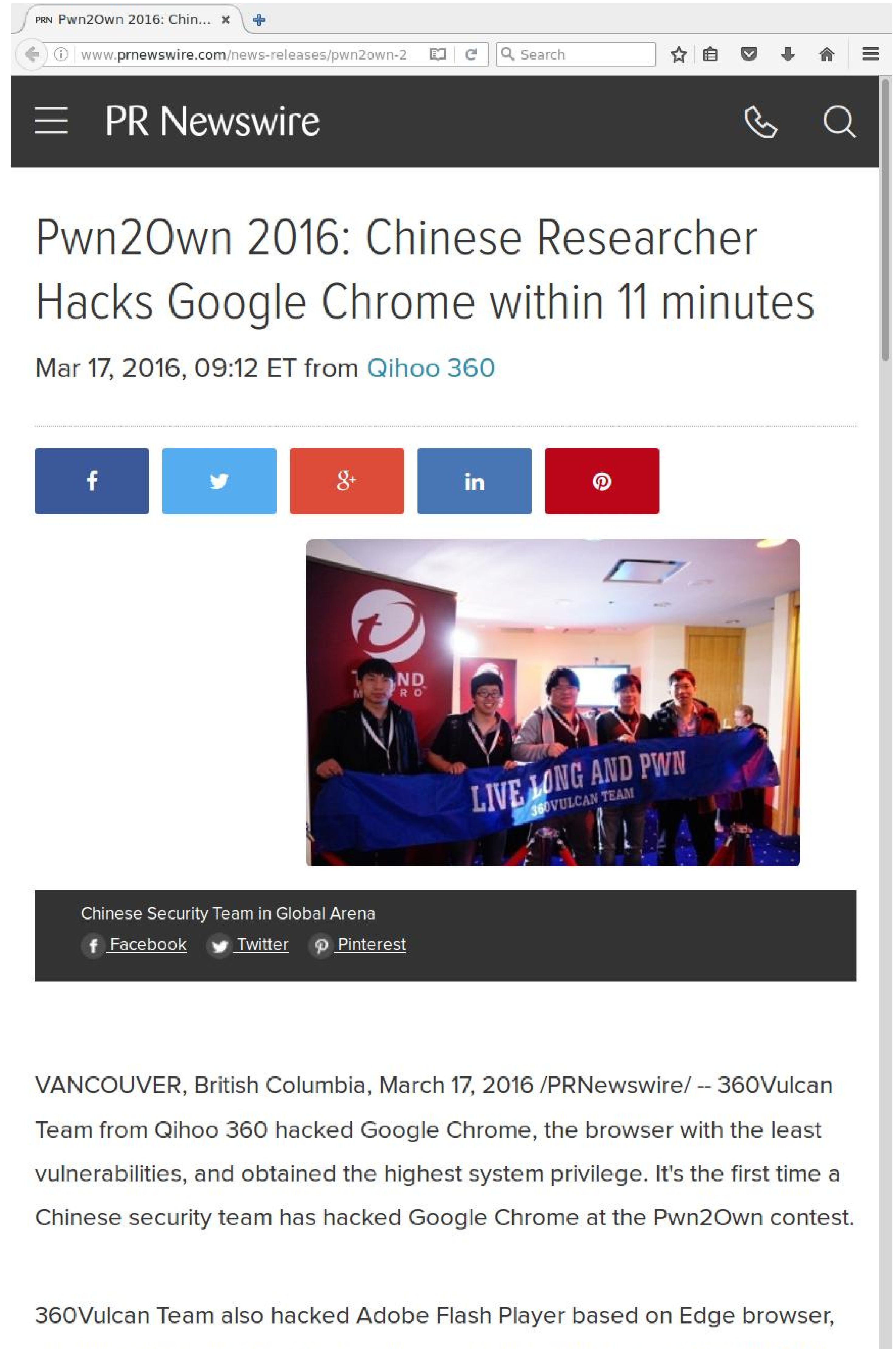

Pwn2Own 2016: Chin...

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PR Newswire

Pwn2Own 2016: Chinese Researcher Hacks Google Chrome within 11 minutes

Mar 17, 2016, 09:12 ET from Qihoo 360

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VANCOUVER, British Columbia, March 17, 2016 /PRNewswire/ -- 360Vulcan Team from Qihoo 360 hacked Google Chrome, the browser with the least vulnerabilities, and obtained the highest system privilege. It's the first time a Chinese security team has hacked Google Chrome at the Pwn2Own contest.

360Vulcan Team also hacked Adobe Flash Player based on Edge browser, obtaining the highest system privilege, which won the team a USD 80,000 *want* communication!

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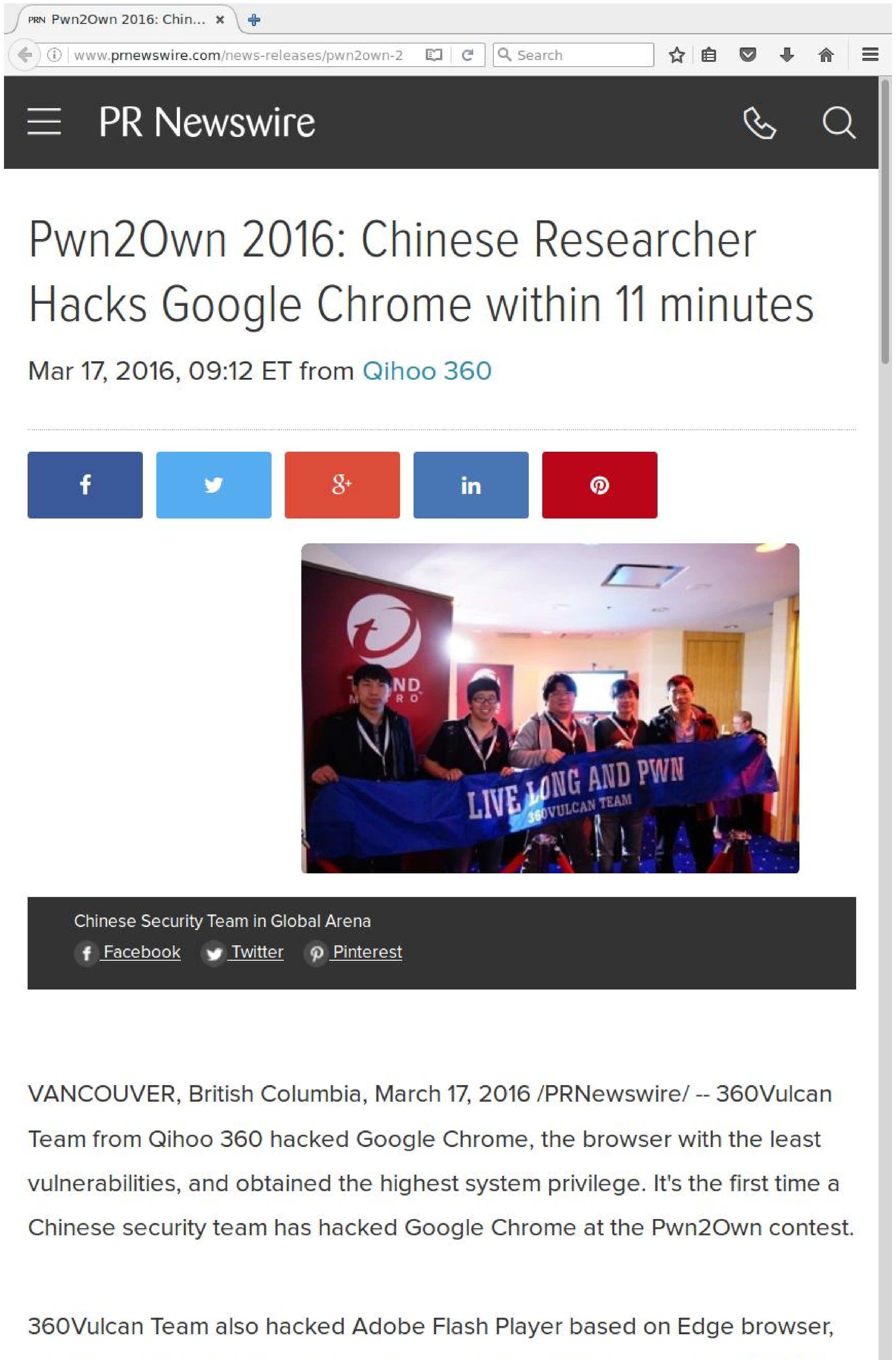

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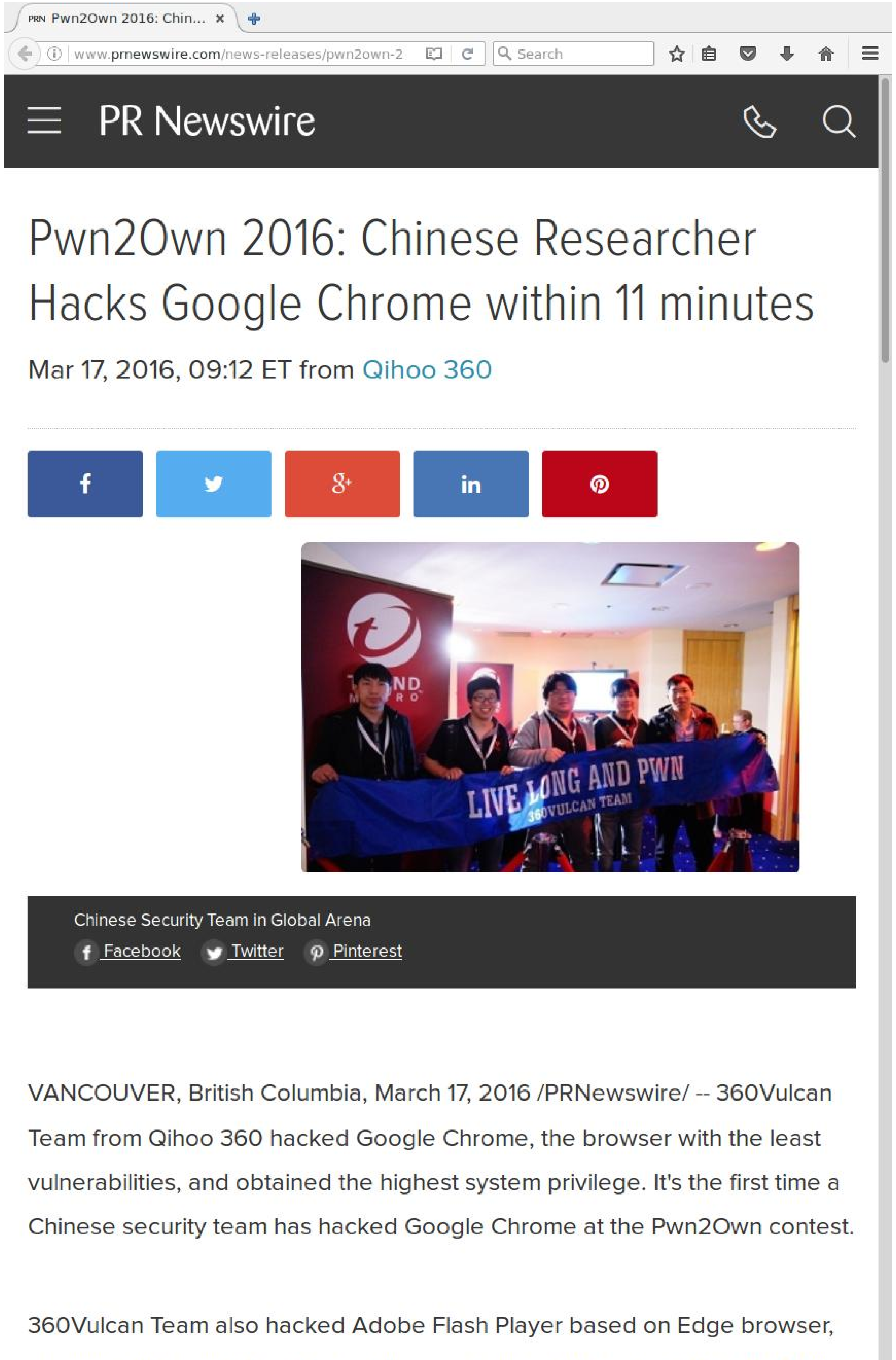
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There is some “security” code inside kernel and browser.
But bugs in other code
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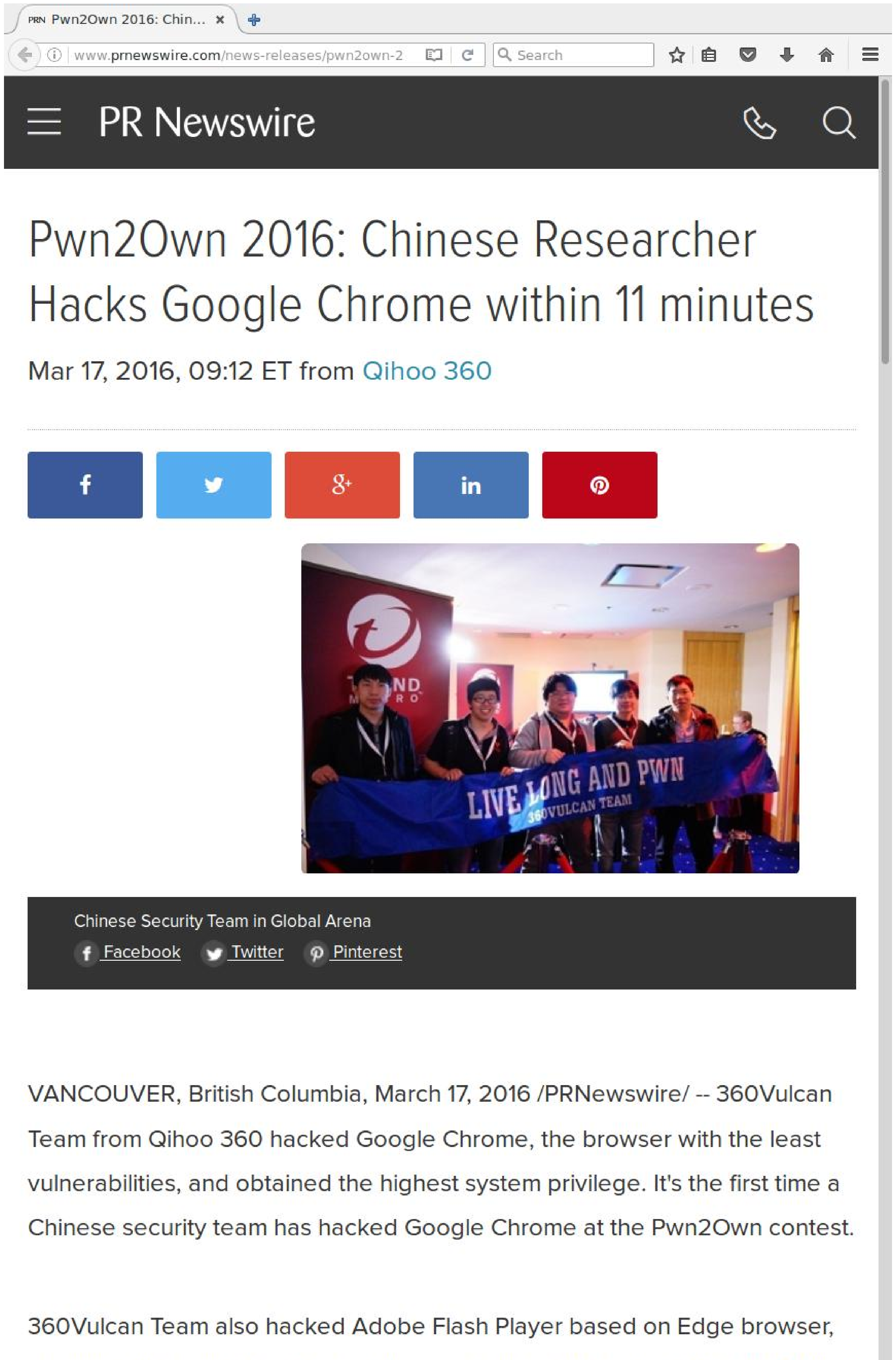
TCB has >30000000 lines.



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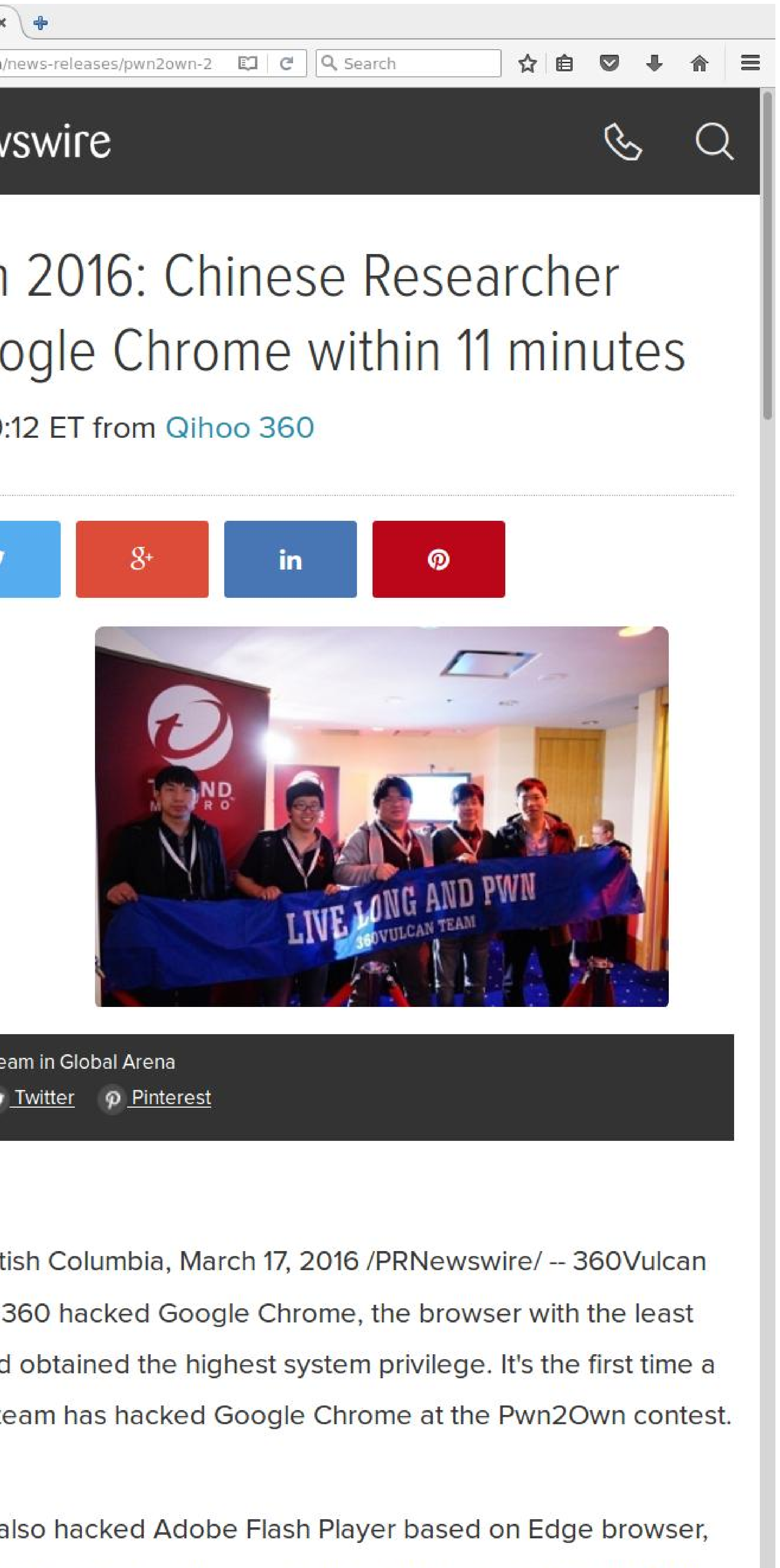
Eliminate all bugs in TCB.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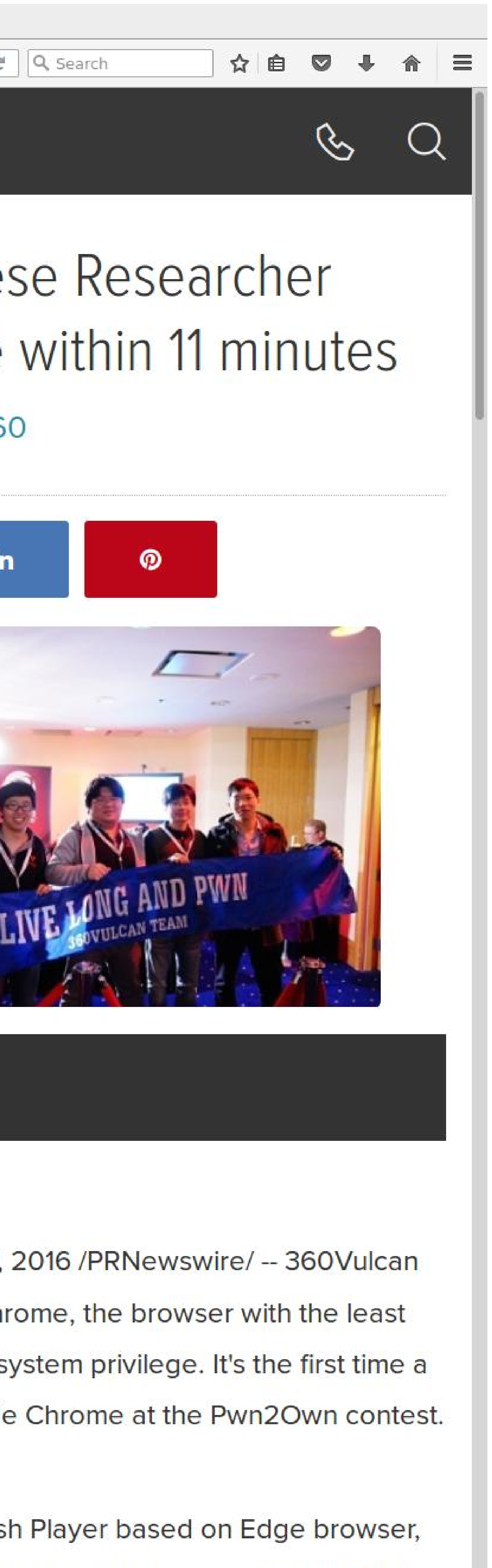

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What happens if data is sent through Donald's network?

Solution: Sender and receiver scramble communication in a way that Donald cannot understand and cannot silently corrupt.

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Most important answer:
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(Same issue elsewhere in TCB,
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e.g. ECDSA signature verification:
$(H(M)/S)B + (x(R)/S)A = R$,
with S checked to be nonzero.

OpenSSL has complicated code for fast computation of $1/S$.

Checking $H(M)B + x(R)A = SR$ would be somewhat slower.

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$2^{256} - 2^{224} + 2^{192}$

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Write A as
$(A_{15}, A_{14}, A_{13}, A_{1}$
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e.g. NIST P-256 prime p is
$2^{256} - 2^{224} + 2^{192} + 2^{96} -$ 1

ECDSA standard specifies reduction procedure given an integer "A less than p^2":

Write A as
$(A_{15}, A_{14}, A_{13}, A_{12}, A_{11}, A_{10}$
$A_8, A_7, A_6, A_5, A_4, A_3, A_2,$
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Define
$T; S_1; S_2; S_3; S_4; D_1; D_2; D_3$
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$(A_7, A_6,$
$(A_{15}, A_1$
$(0, A_{15},$
$(A_{15}, A_1$
$(A_8, A_{13}$
$(A_{10}, A_8$
$(A_{11}, A_9$
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$(A_{15}, A_{14}, A_{13}, A_{12}$
$(0, A_{15}, A_{14}, A_{13},$
$(A_{15}, A_{14}, 0, 0, 0,$
$(A_8, A_{13}, A_{15}, A_{14},$
$(A_{10}, A_8, 0, 0, 0, A_1$
$(A_{11}, A_9, 0, 0, A_{15},$
$(A_{12}, 0, A_{10}, A_9, A_8$
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Compute $T + 2S_1$
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$(A_{15}, A_{14}, A_{13}, A_{12}, A_{11}, 0, 0$
$(0, A_{15}, A_{14}, A_{13}, A_{12}, 0, 0, 0)$
$(A_{15}, A_{14}, 0, 0, 0, A_{10}, A_9, A_8$
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Compute $T + 2S_1 + 2S_2 +$
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Reduce modulo p "by addin
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Define $T; S_1; S_2; S_3; S_4; D_1; D_2; D_3; D_4$ as

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$(A_{15}, A_{14}, A_{13}, A_{12}, A_{11}, 0, 0, 0)$;
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$(A_{15}, A_{14}, 0, 0, 0, A_{10}, A_9, A_8)$;
$(A_8, A_{13}, A_{15}, A_{14}, A_{13}, A_{11}, A_{10}, A_9)$;
$(A_{10}, A_8, 0, 0, 0, A_{13}, A_{12}, A_{11})$;
$(A_{11}, A_9, 0, 0, A_{15}, A_{14}, A_{13}, A_{12})$;
$(A_{12}, 0, A_{10}, A_9, A_8, A_{15}, A_{14}, A_{13})$;
$(A_{13}, 0, A_{11}, A_{10}, A_9, 0, A_{15}, A_{14})$.

Compute $T + 2S_1 + 2S_2 + S_3 + S_4 - D_1 - D_2 - D_3 - D_4$.

Reduce modulo p "by adding or subtracting a few copies" of p.

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; $\sum_i A_i 2^{32i}$.

$_2; S_3; S_4; D_1; D_2; D_3; D_4$

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$(A_{15}, A_{14}, 0, 0, 0, A_{10}, A_9, A_8)$;
$(A_8, A_{13}, A_{15}, A_{14}, A_{13}, A_{11}, A_{10}, A_9)$;
$(A_{10}, A_8, 0, 0, 0, A_{13}, A_{12}, A_{11})$;
$(A_{11}, A_9, 0, 0, A_{15}, A_{14}, A_{13}, A_{12})$;
$(A_{12}, 0, A_{10}, A_9, A_8, A_{15}, A_{14}, A_{13})$;
$(A_{13}, 0, A_{11}, A_{10}, A_9, 0, A_{15}, A_{14})$.

Compute $T + 2S_1 + 2S_2 + S_3 + S_4 - D_1 - D_2 - D_3 - D_4$.

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Compute $T + 2S_1 + 2S_2 + S_3 + S_4 - D_1 - D_2 - D_3 - D_4$.

Reduce modulo p "by adding or subtracting a few copies" of p.

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One of my favorite
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$(A_{15}, A_{14}, A_{13}, A_{12}, A_{11}, 0, 0, 0);$
$(0, A_{15}, A_{14}, A_{13}, A_{12}, 0, 0, 0);$
$(A_{15}, A_{14}, 0, 0, 0, A_{10}, A_9, A_8);$
$(A_8, A_{13}, A_{15}, A_{14}, A_{13}, A_{11}, A_{10}, A_9);$
$(A_{10}, A_8, 0, 0, 0, A_{13}, A_{12}, A_{11});$
$(A_{11}, A_9, 0, 0, A_{15}, A_{14}, A_{13}, A_{12});$
$(A_{12}, 0, A_{10}, A_9, A_8, A_{15}, A_{14}, A_{13});$
$(A_{13}, 0, A_{11}, A_{10}, A_9, 0, A_{15}, A_{14}).$

Compute $T + 2S_1 + 2S_2 + S_3 + S_4 - D_1 - D_2 - D_3 - D_4$.

Reduce modulo p "by adding or subtracting a few copies" of p.

<u>Next-generation crypto</u>

One of my favorite topics: removing tensions between security, simplicity, speed.

In particular, designing simple high-security crypto setting new speed records.

e.g. 2006 Bernstein "Curve2
is twice as fast as standard
and much simpler to implem

$>$1000000000 Curve25519 u
today: iOS, Signal, OpenSS
Tor, QUIC, WhatsApp, more

$(A_7, A_6, A_5, A_4, A_3, A_2, A_1, A_0)$;
$(A_{15}, A_{14}, A_{13}, A_{12}, A_{11}, 0, 0, 0)$;
$(0, A_{15}, A_{14}, A_{13}, A_{12}, 0, 0, 0)$;
$(A_{15}, A_{14}, 0, 0, 0, A_{10}, A_9, A_8)$;
$(A_8, A_{13}, A_{15}, A_{14}, A_{13}, A_{11}, A_{10}, A_9)$;
$(A_{10}, A_8, 0, 0, 0, A_{13}, A_{12}, A_{11})$;
$(A_{11}, A_9, 0, 0, A_{15}, A_{14}, A_{13}, A_{12})$;
$(A_{12}, 0, A_{10}, A_9, A_8, A_{15}, A_{14}, A_{13})$;
$(A_{13}, 0, A_{11}, A_{10}, A_9, 0, A_{15}, A_{14})$.

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$A_5, A_4, A_3, A_2, A_1, A_0)$;

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$A_{14}, A_{13}, A_{12}, 0, 0, 0)$;

$_4, 0, 0, 0, A_{10}, A_9, A_8)$;

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$A_{13}, A_{11}, A_{10}, A_9)$;

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Ask human for occasional annotations expressing high-level computations on integers mod p.

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