Memory-based DoS and Deanonymization Attacks on Tor

DCAPS Seminar

October 11th, 2013

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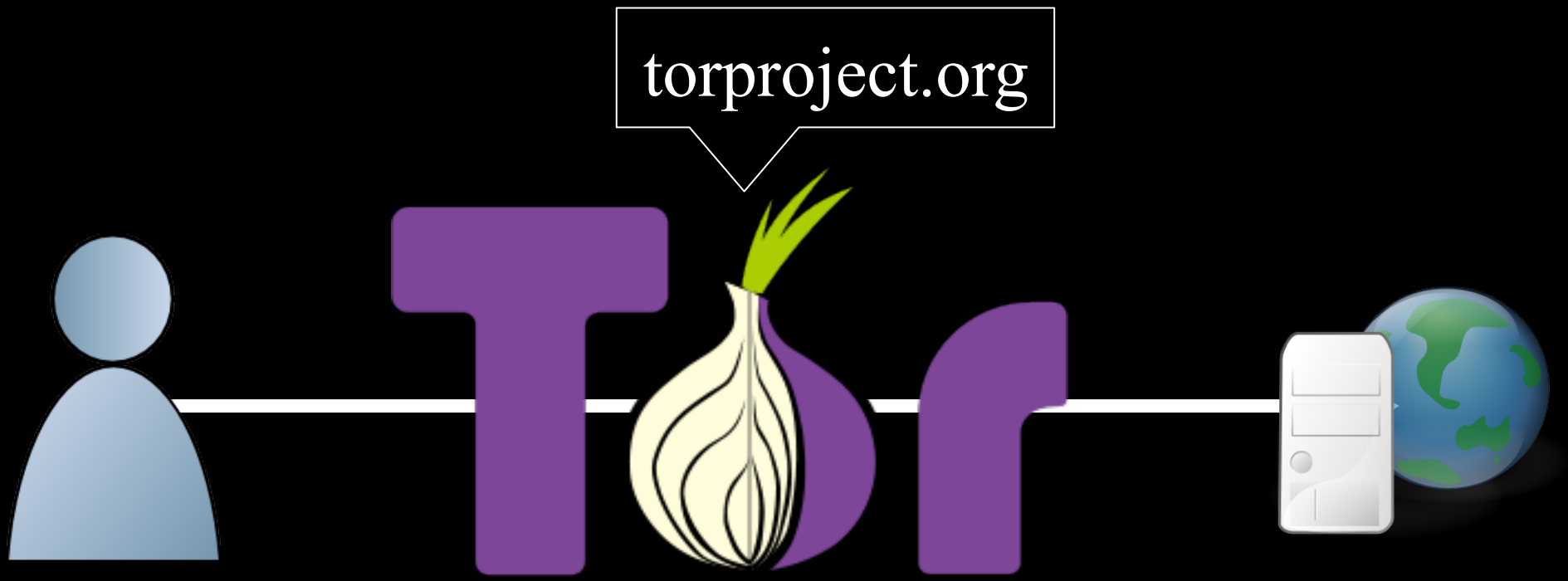
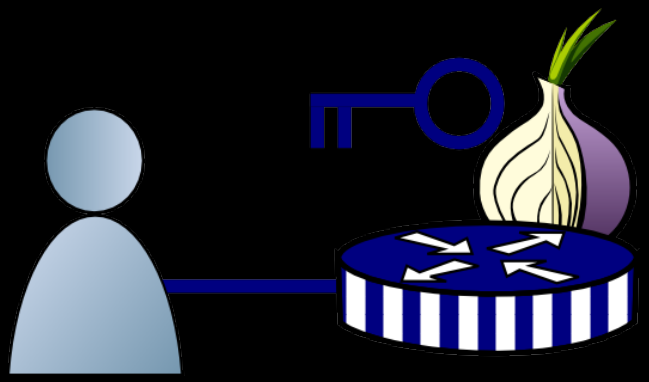
*Joint with Aaron Johnson, Florian Tschorsch, Björn Scheuermann

The Tor Anonymity Network



How Tor Works



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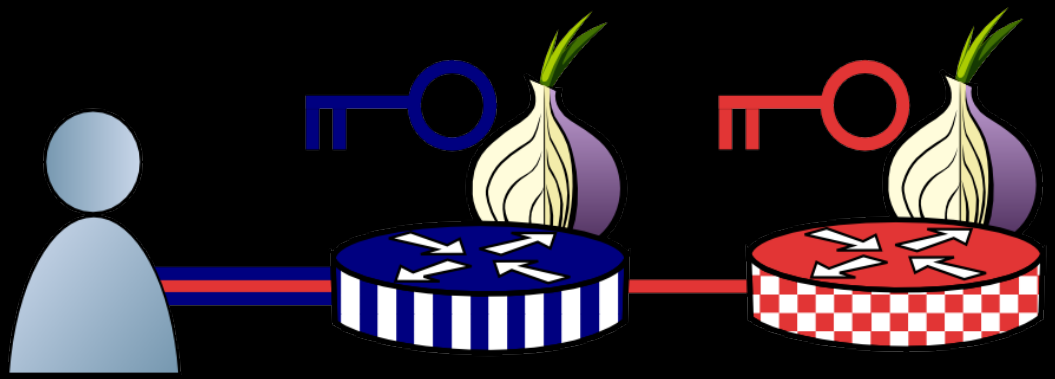

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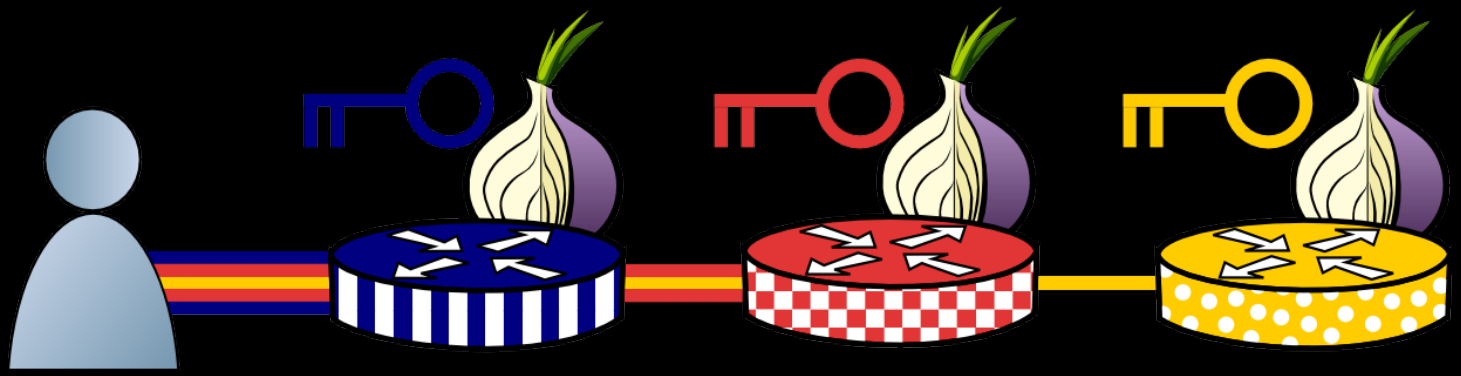

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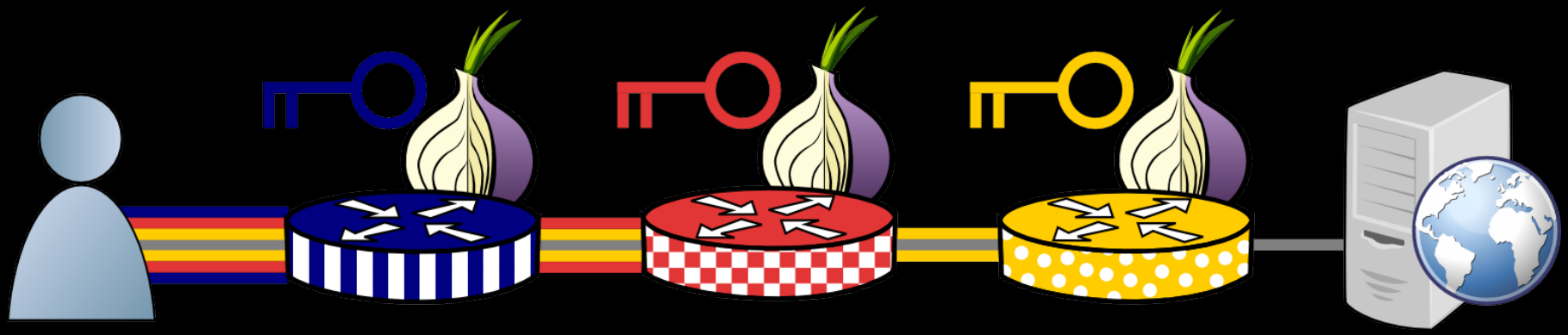

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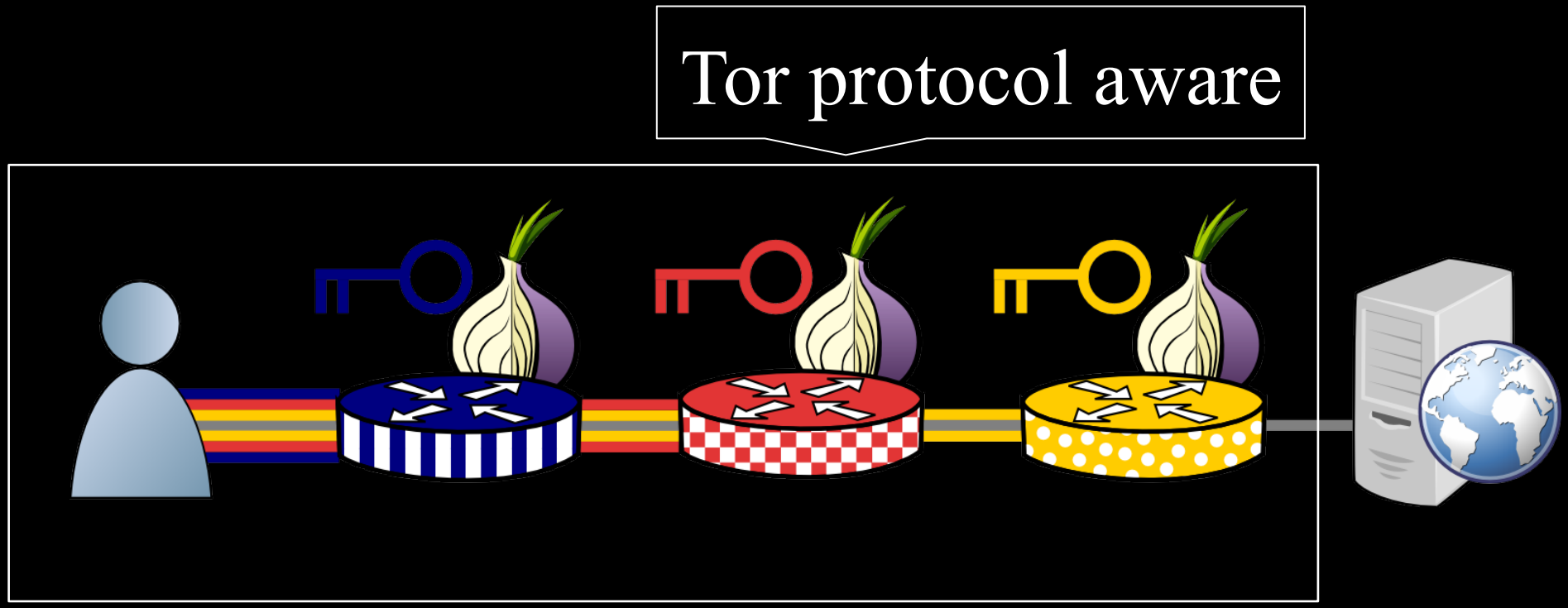
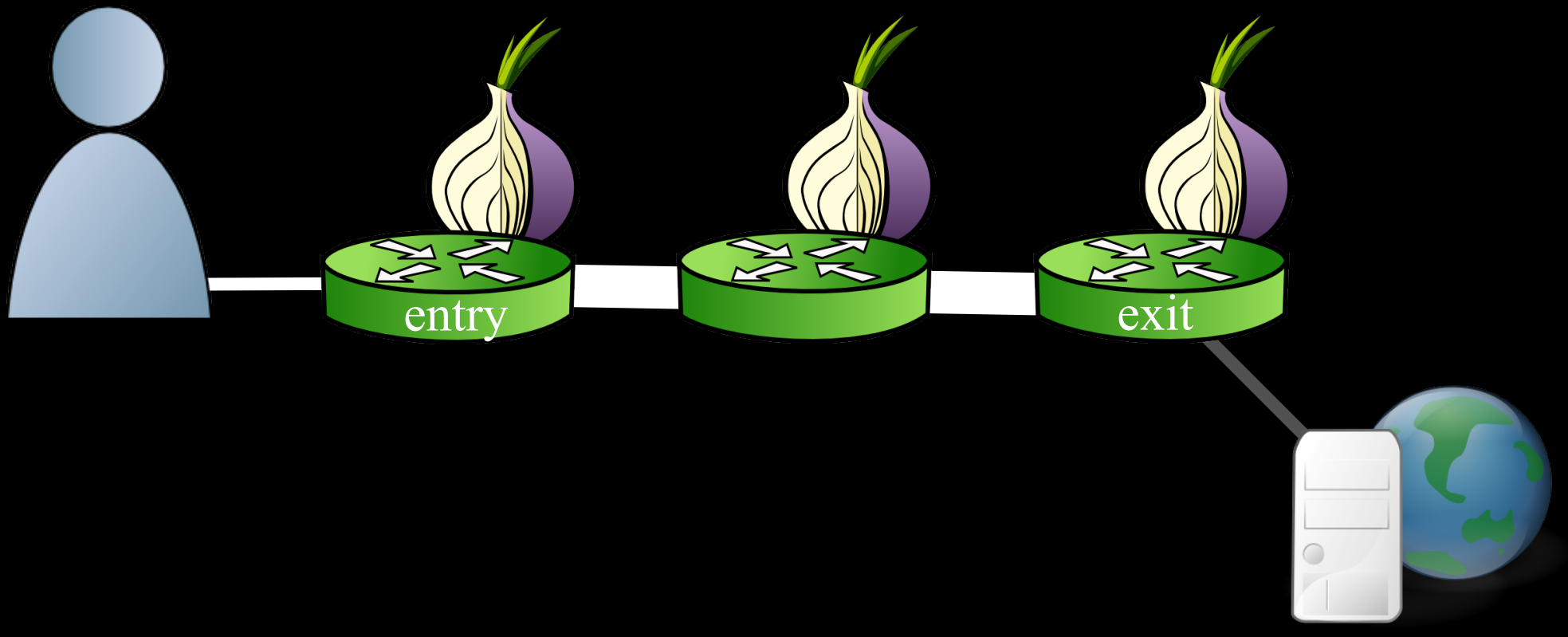


Tor Flow Control



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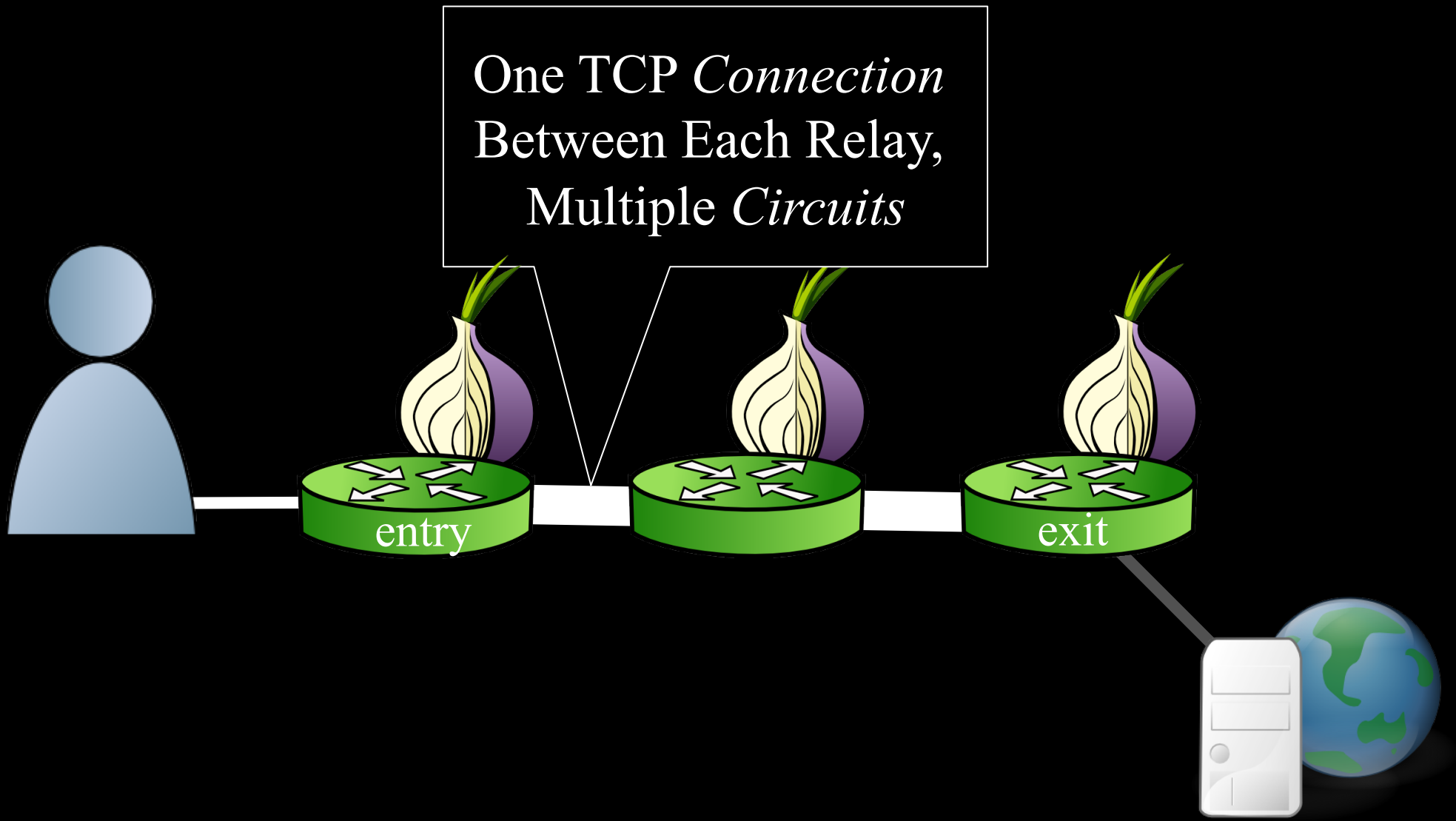

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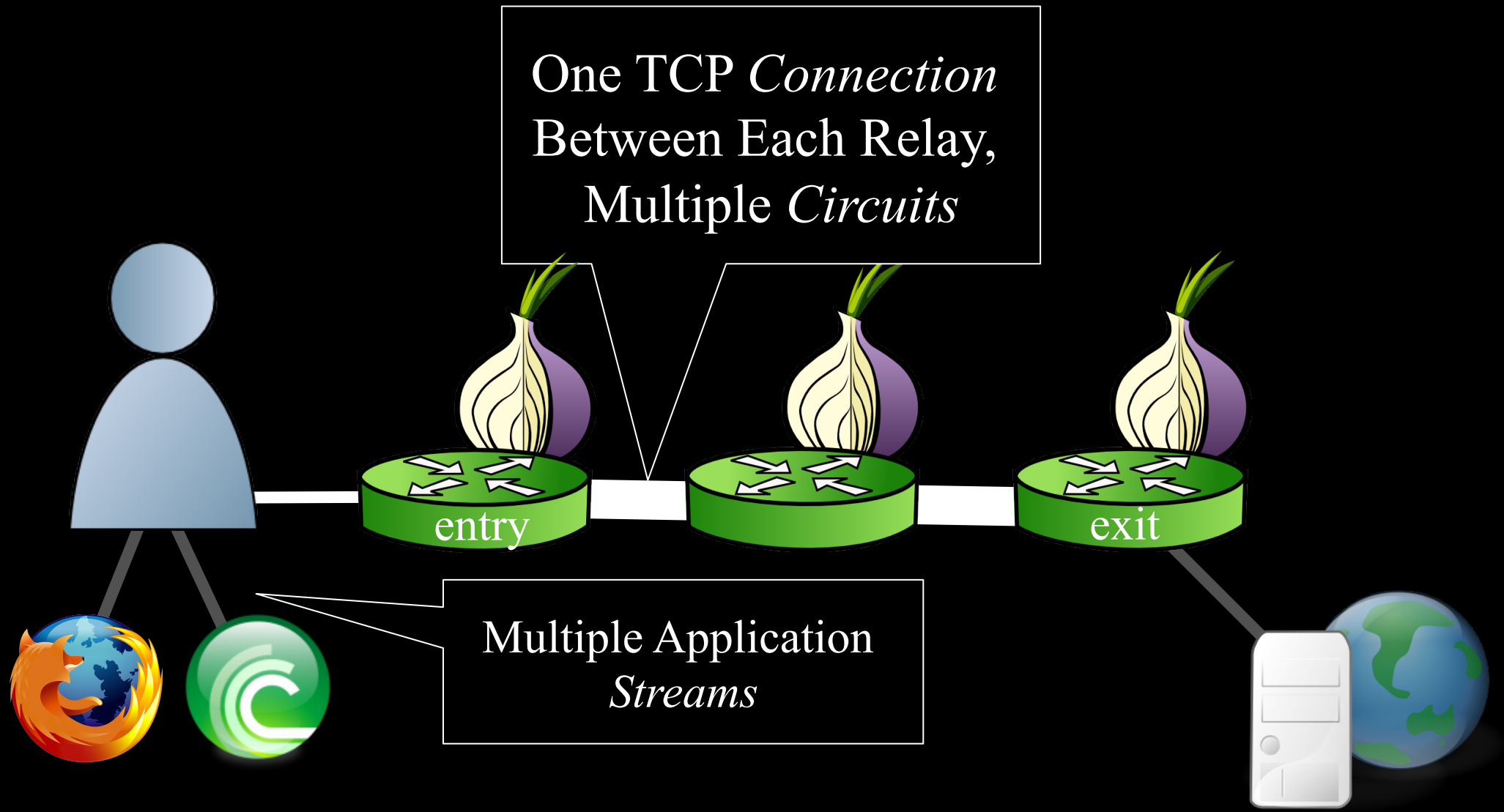

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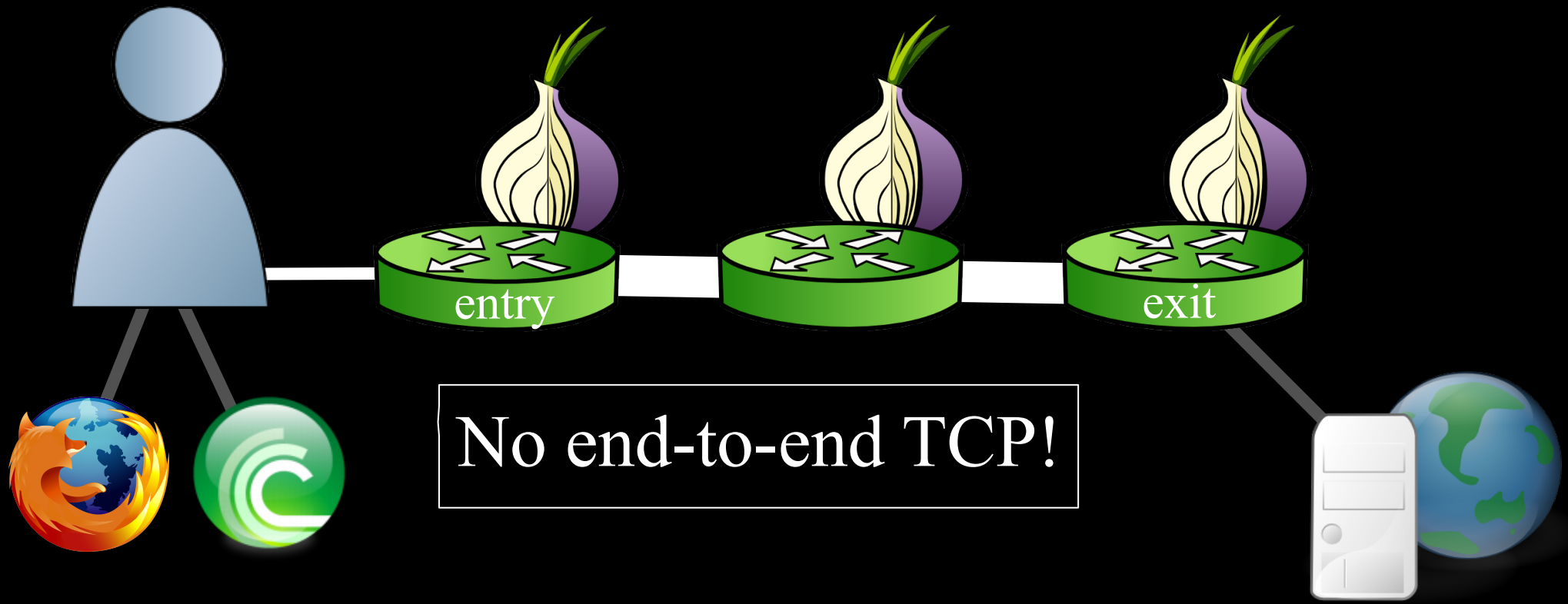

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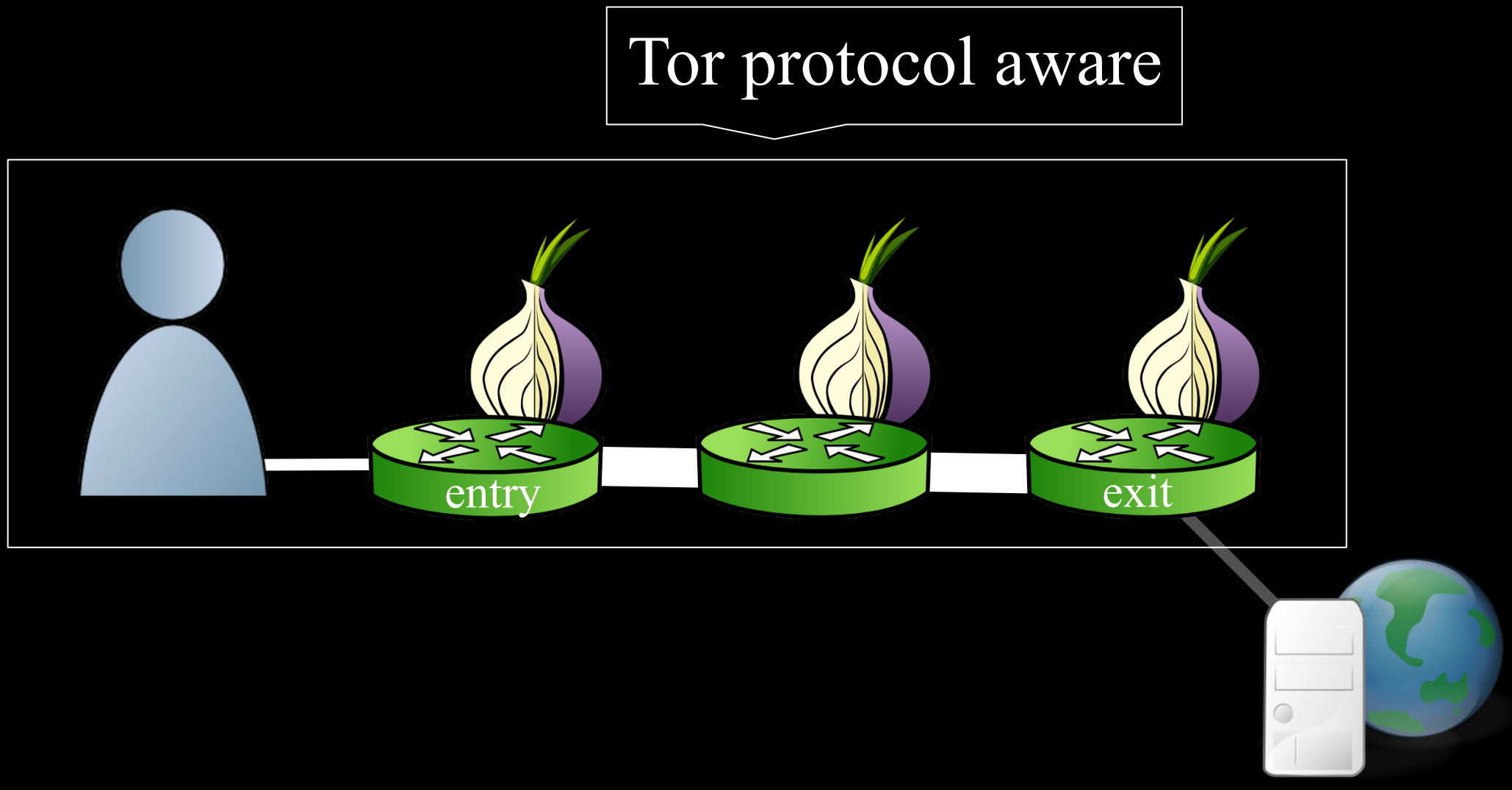

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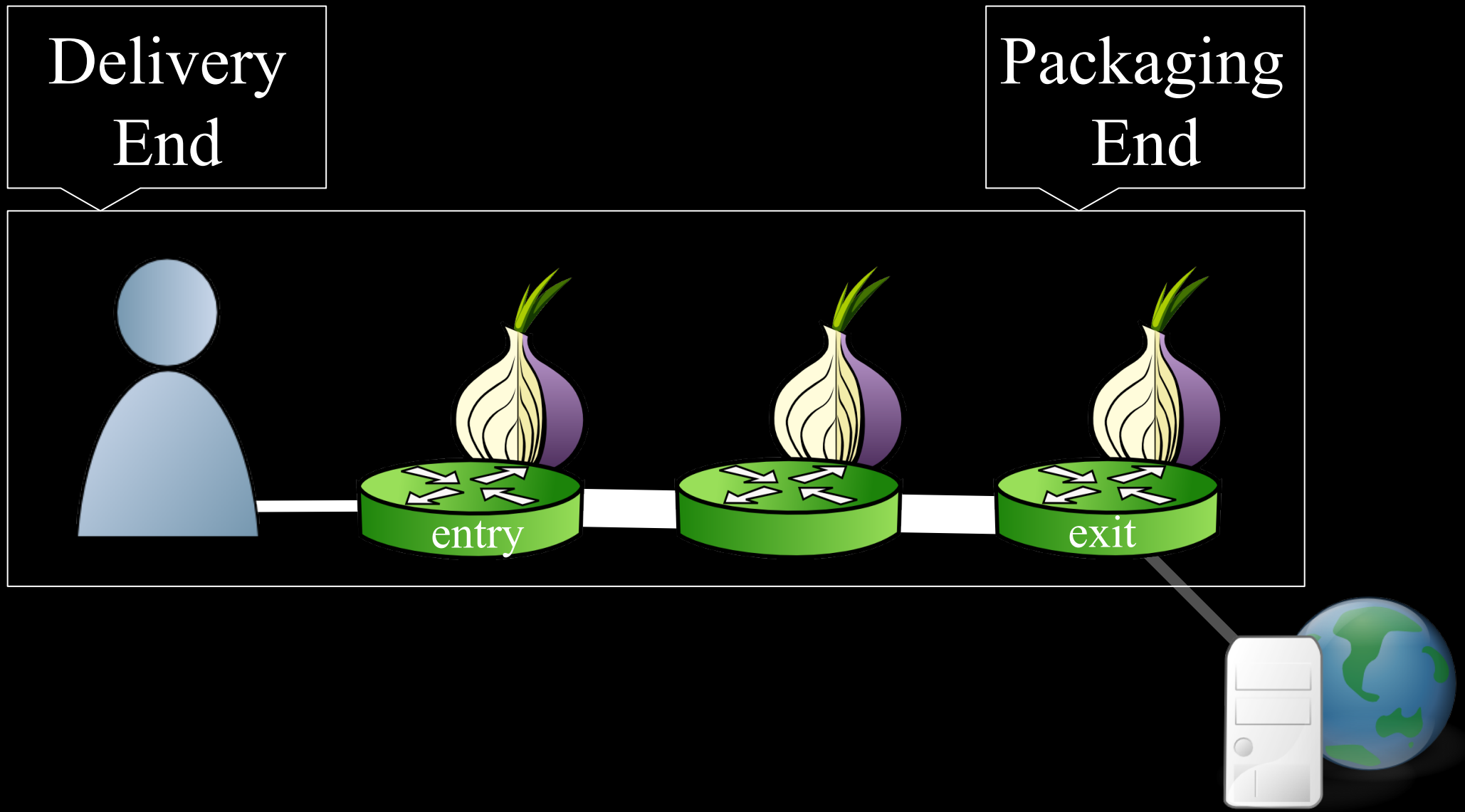

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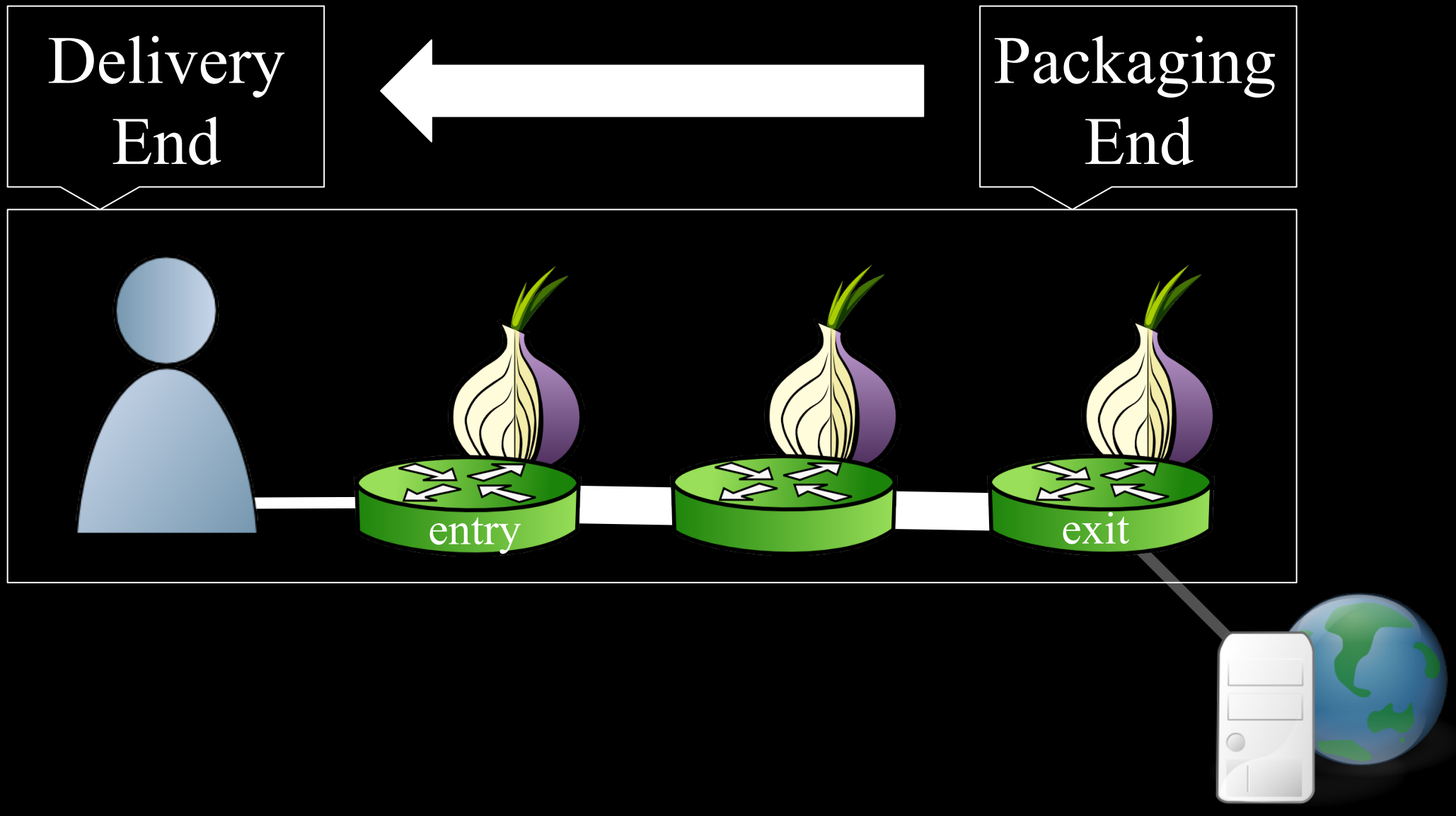
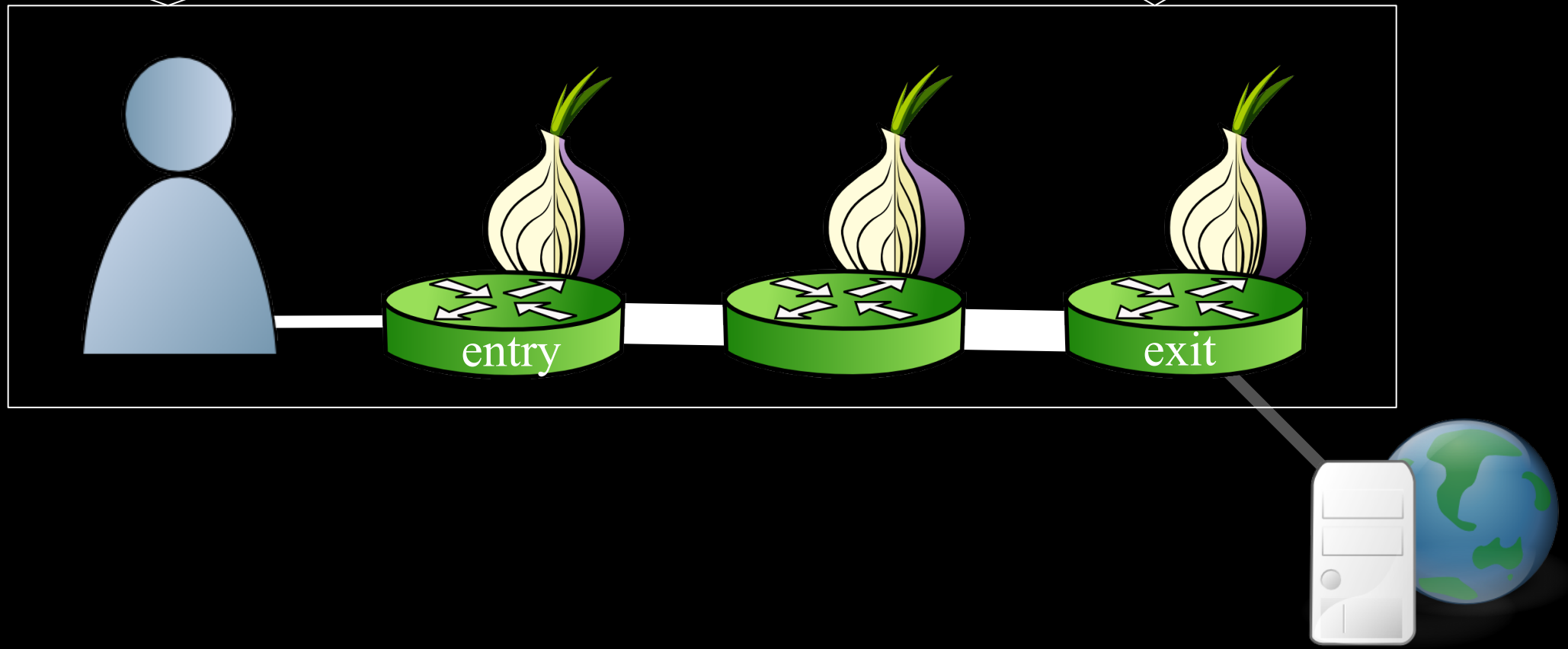


Tor Flow Control

SENDME Signal
Every 100 Cells

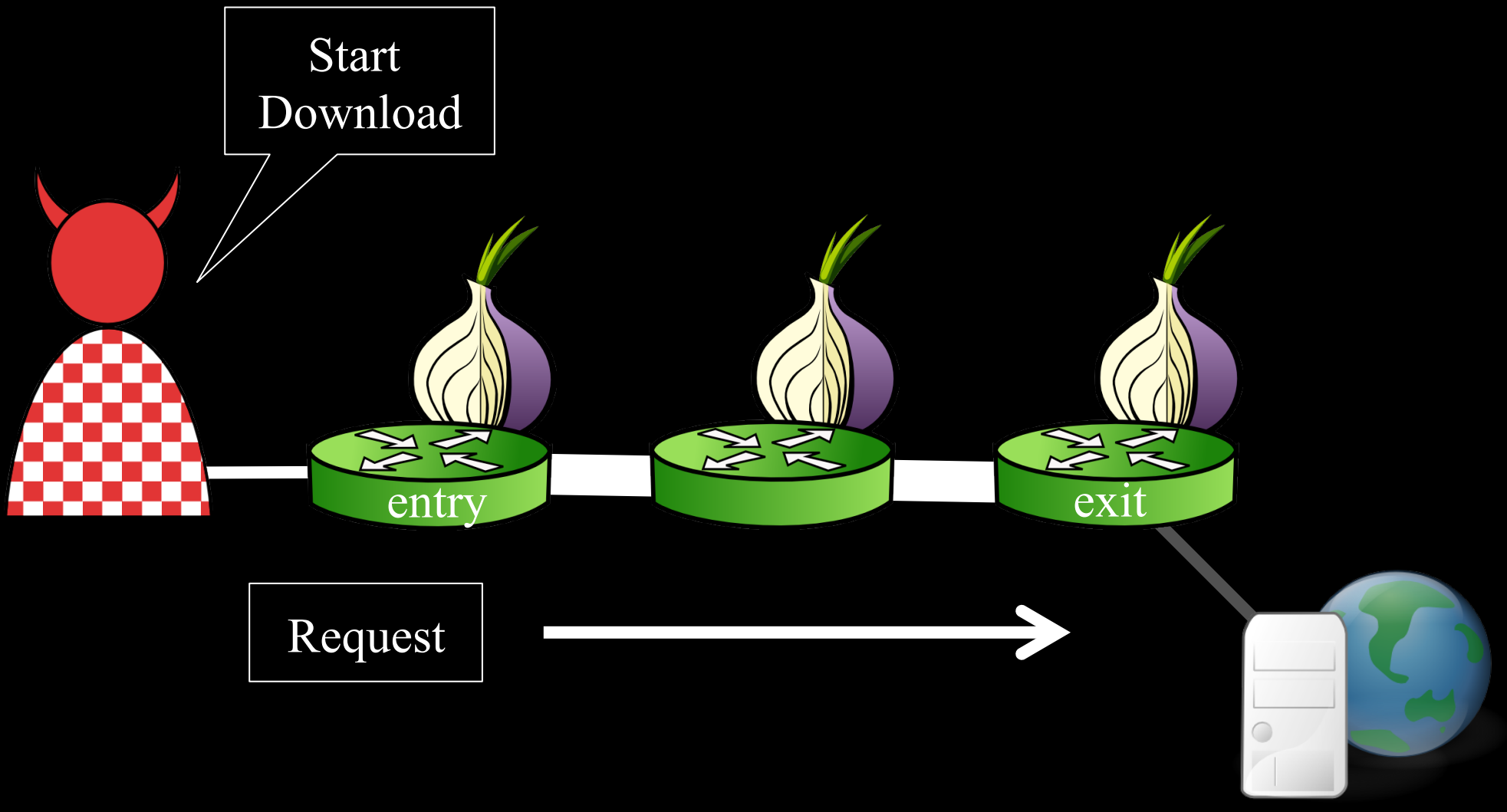
1000 Cell
Limit



Outline

- The Sniper Attack
  - Low-cost memory consumption attack that disables arbitrary Tor relays
- Deanonymizing Hidden Services
  - Using DoS attacks for deanonymization
- Countermeasures

The Sniper Attack



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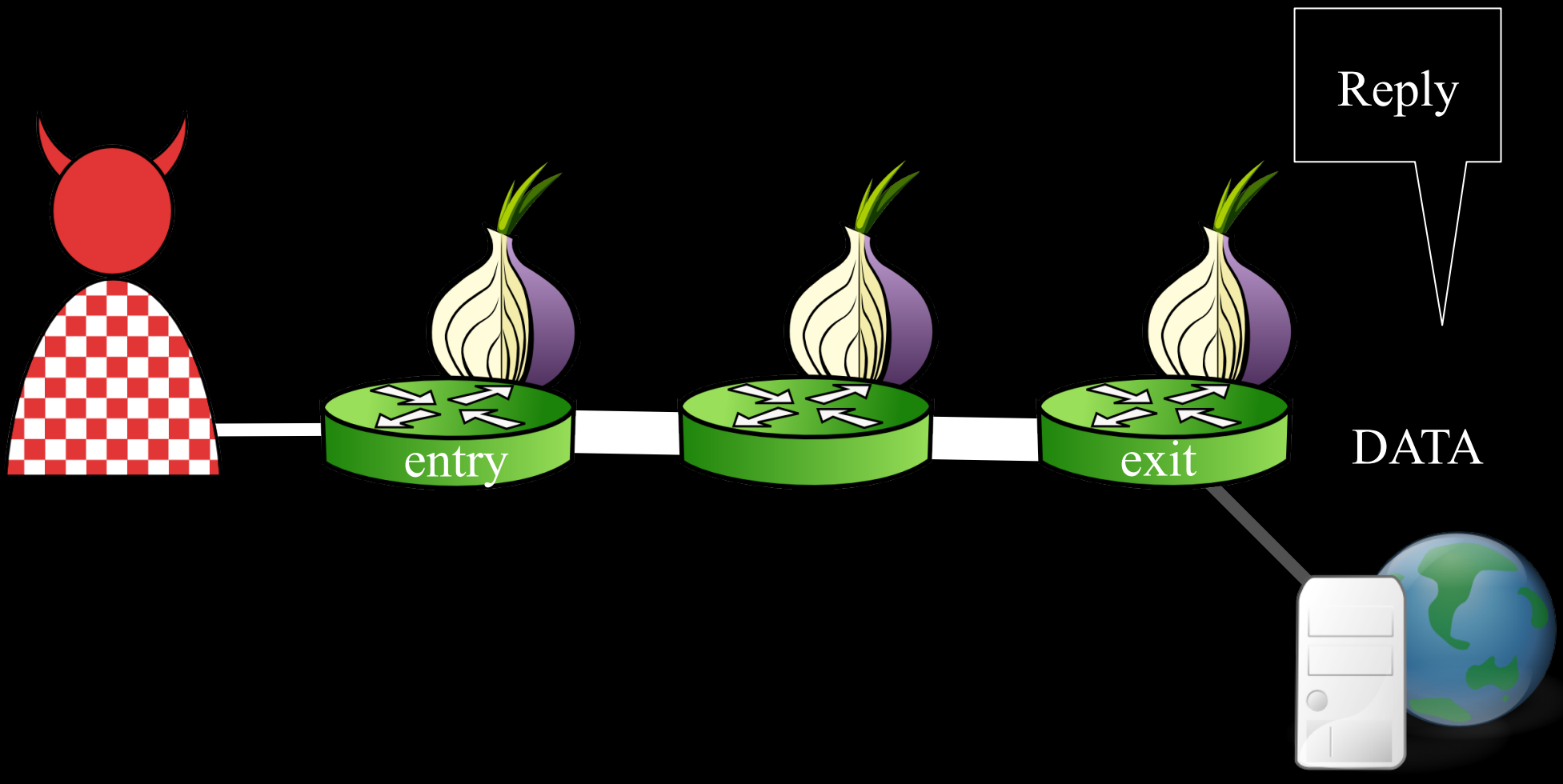

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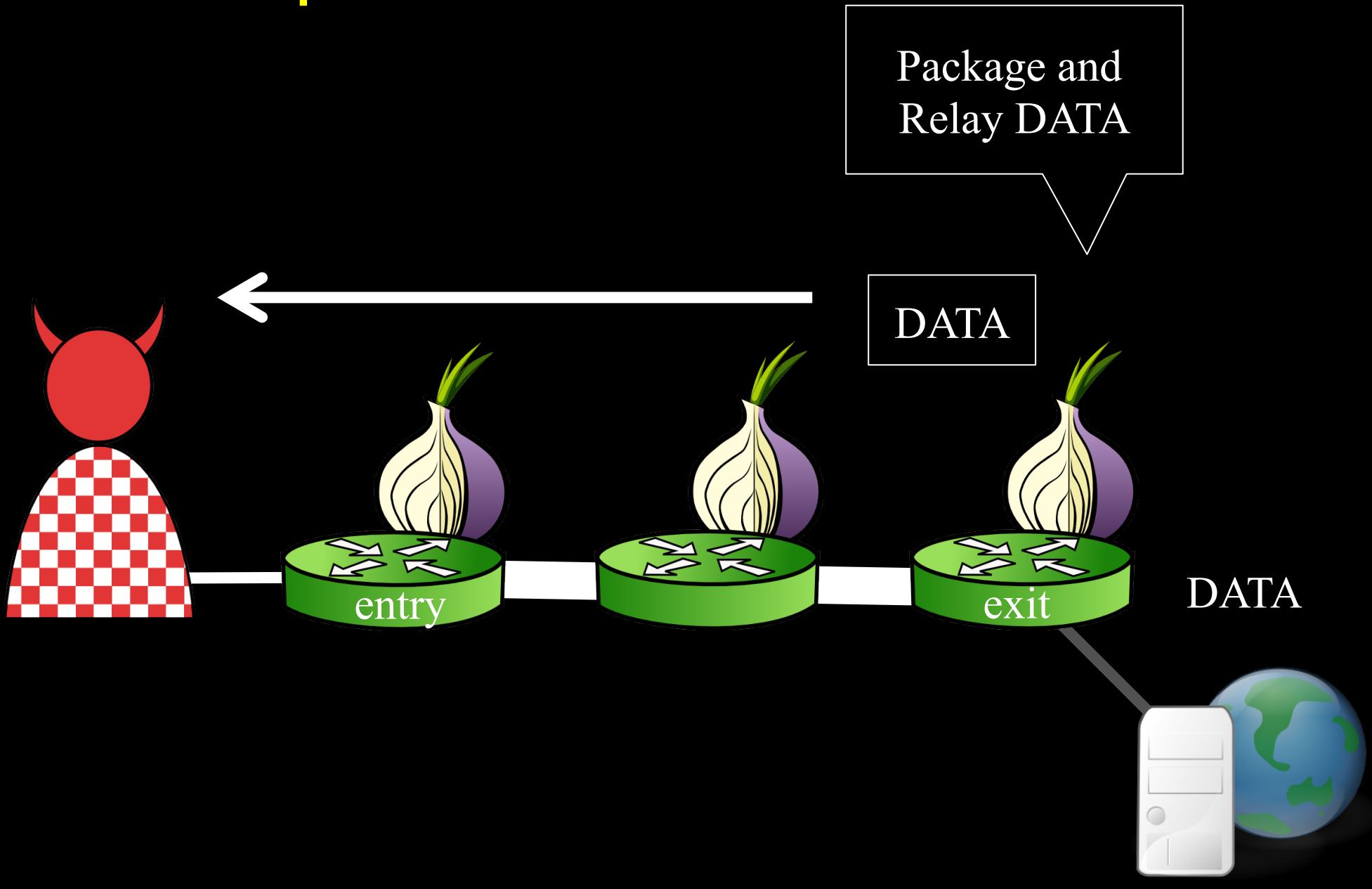

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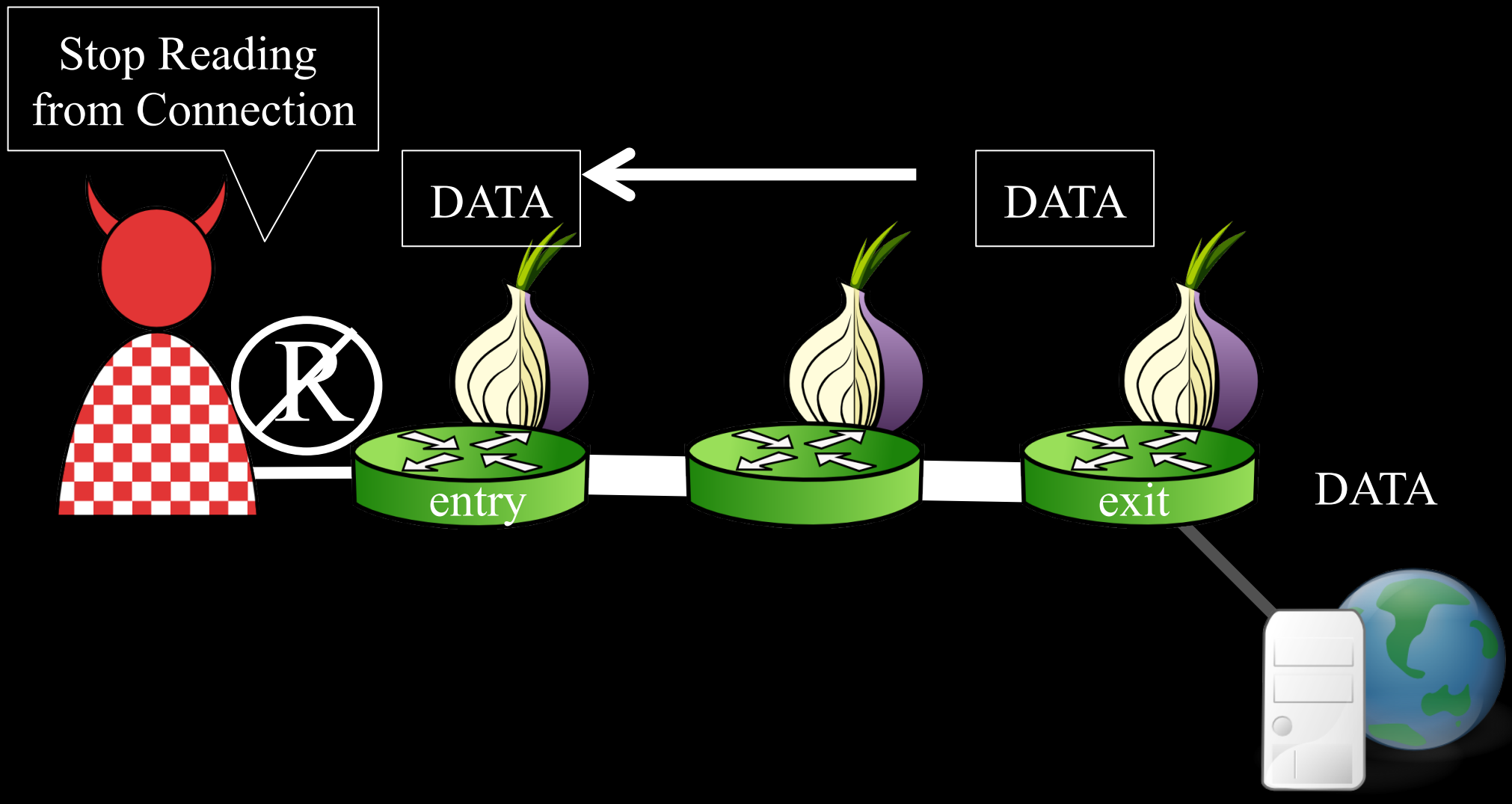

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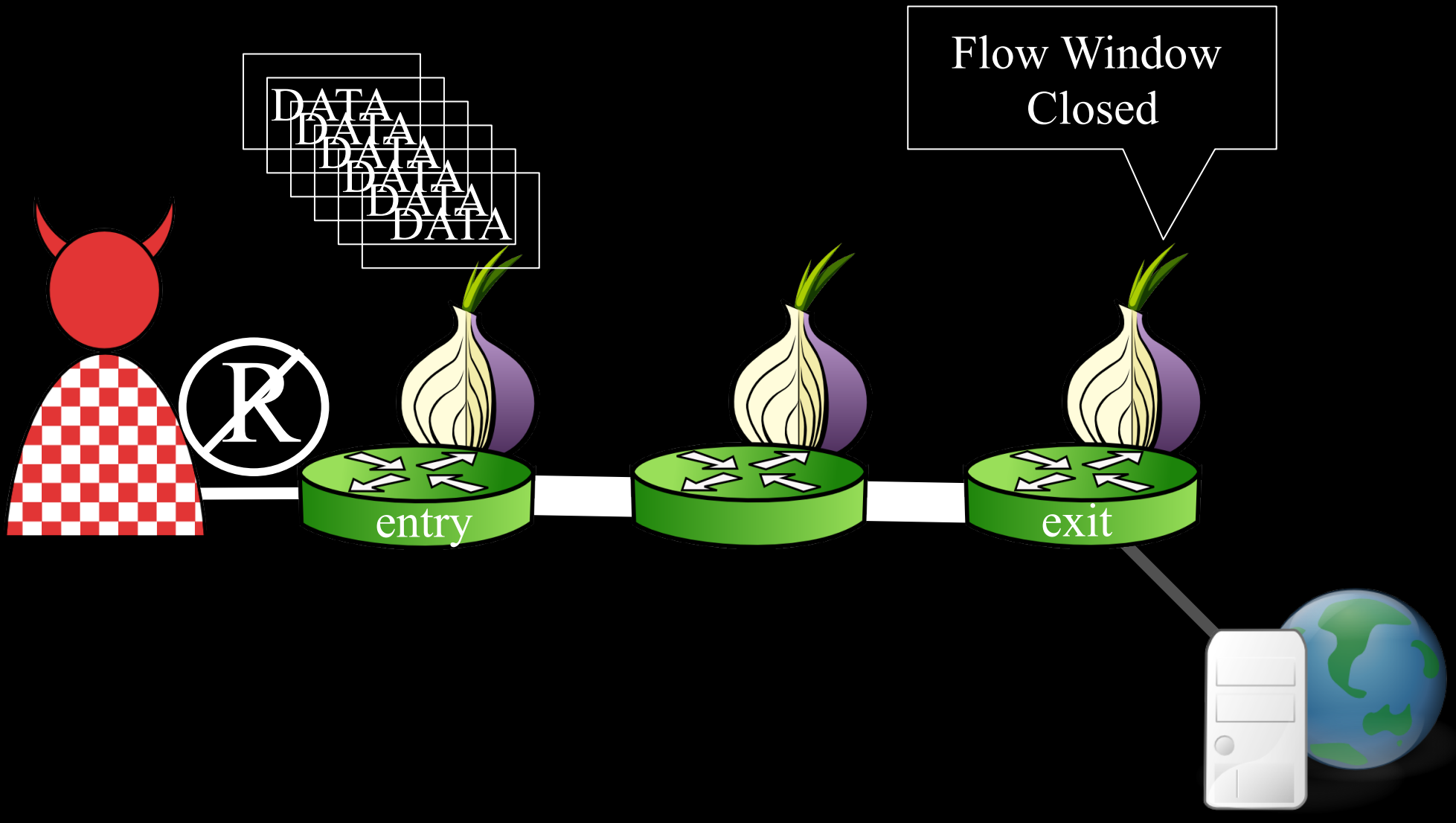

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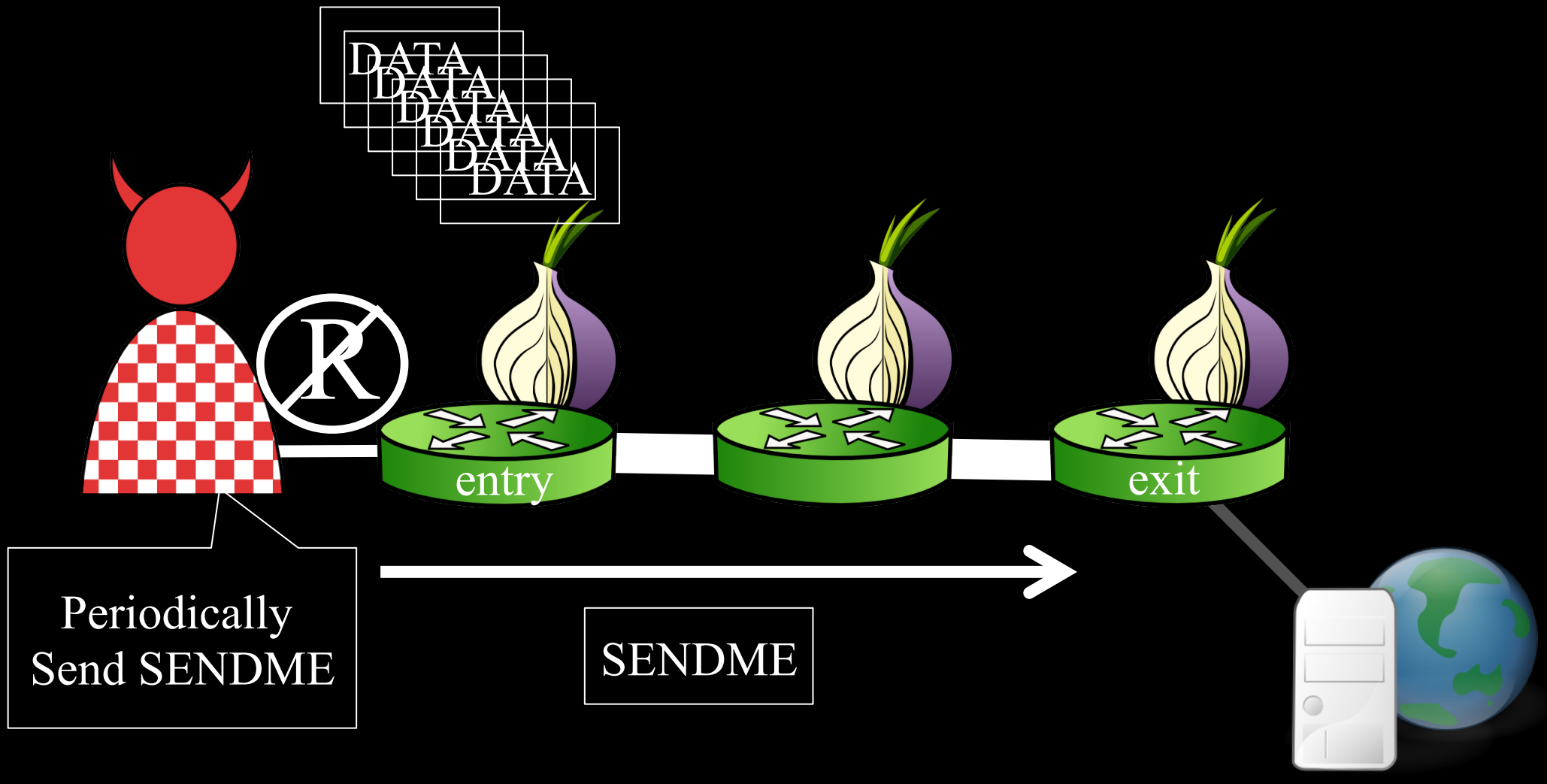

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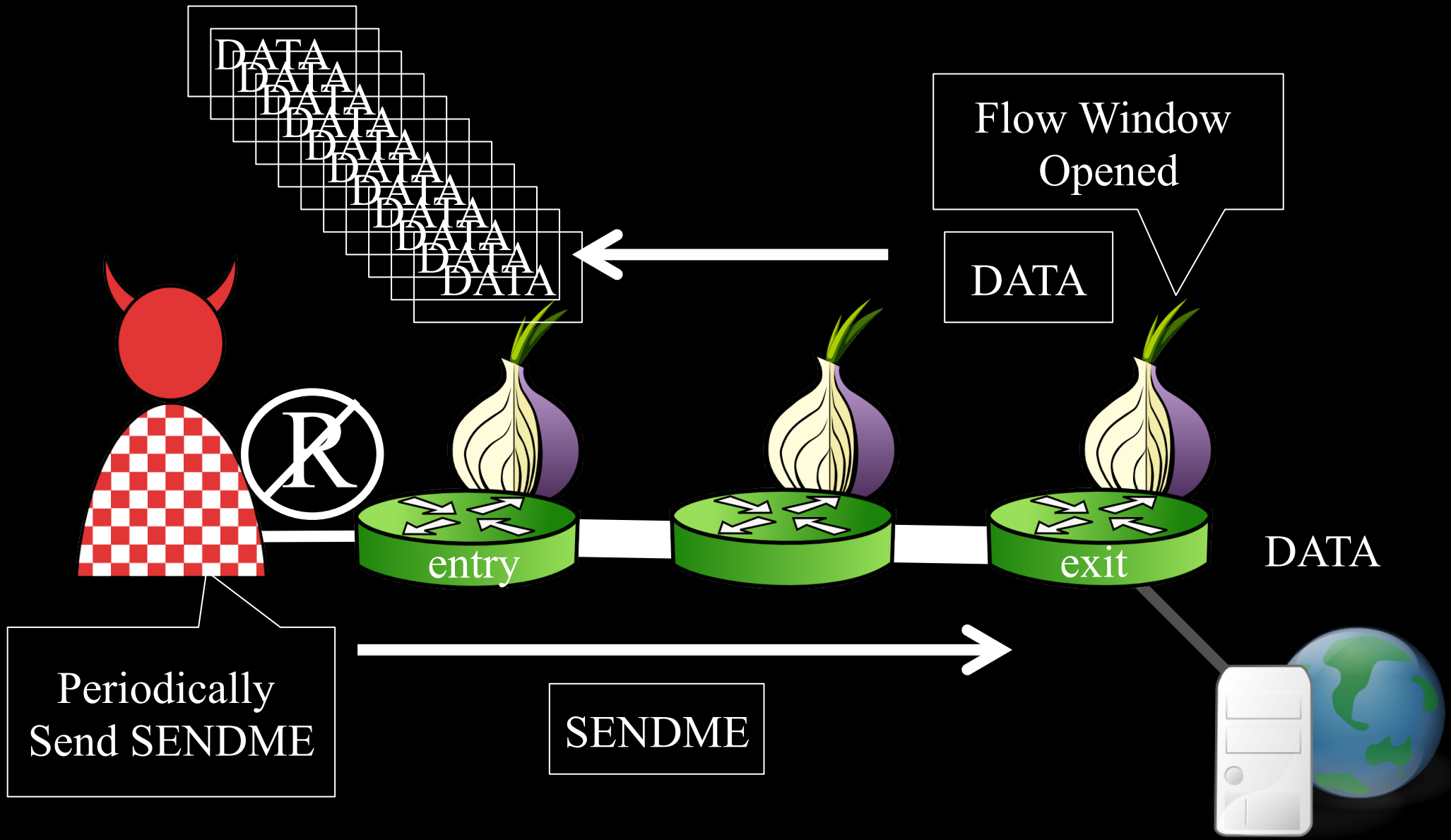

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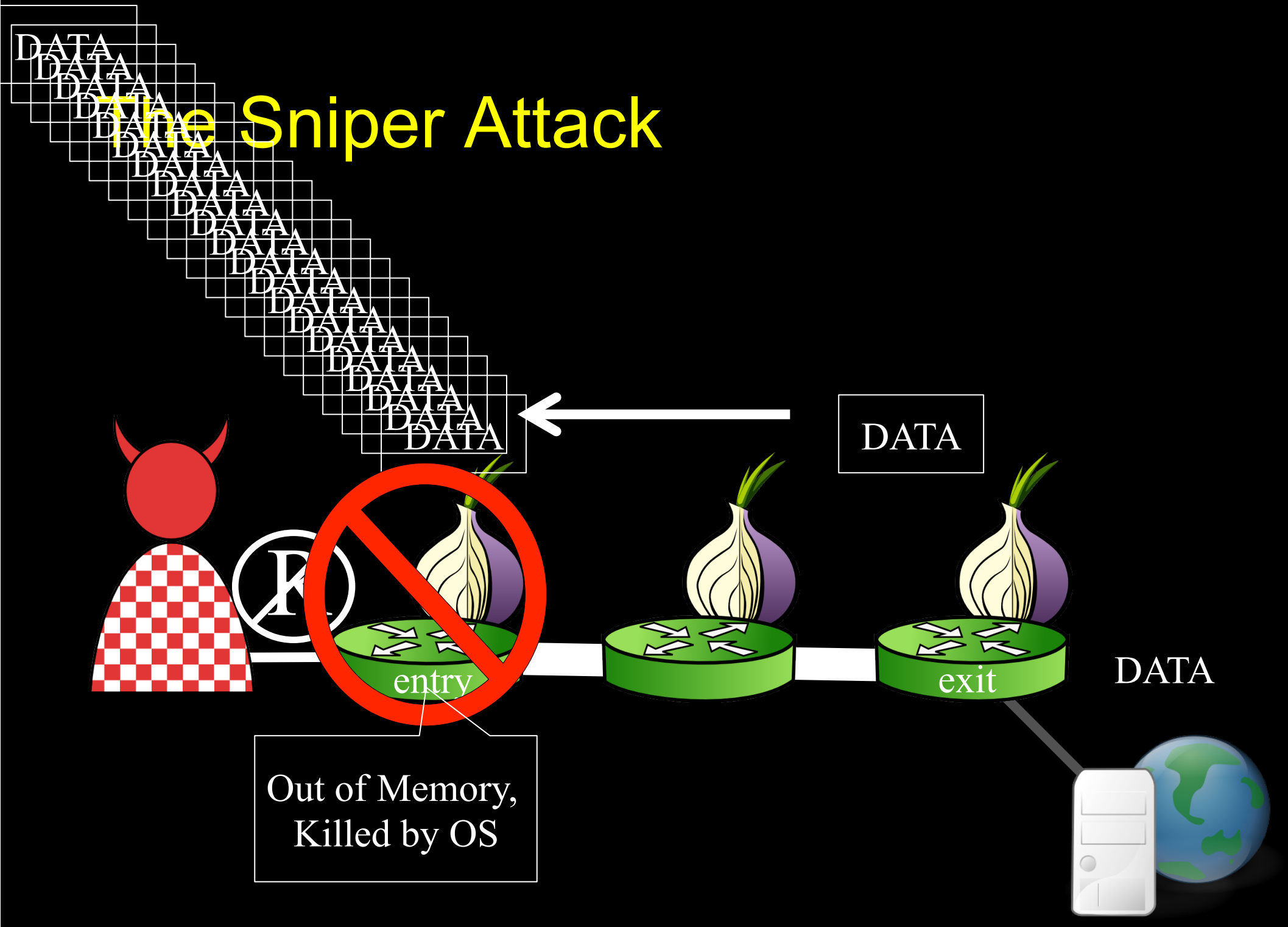

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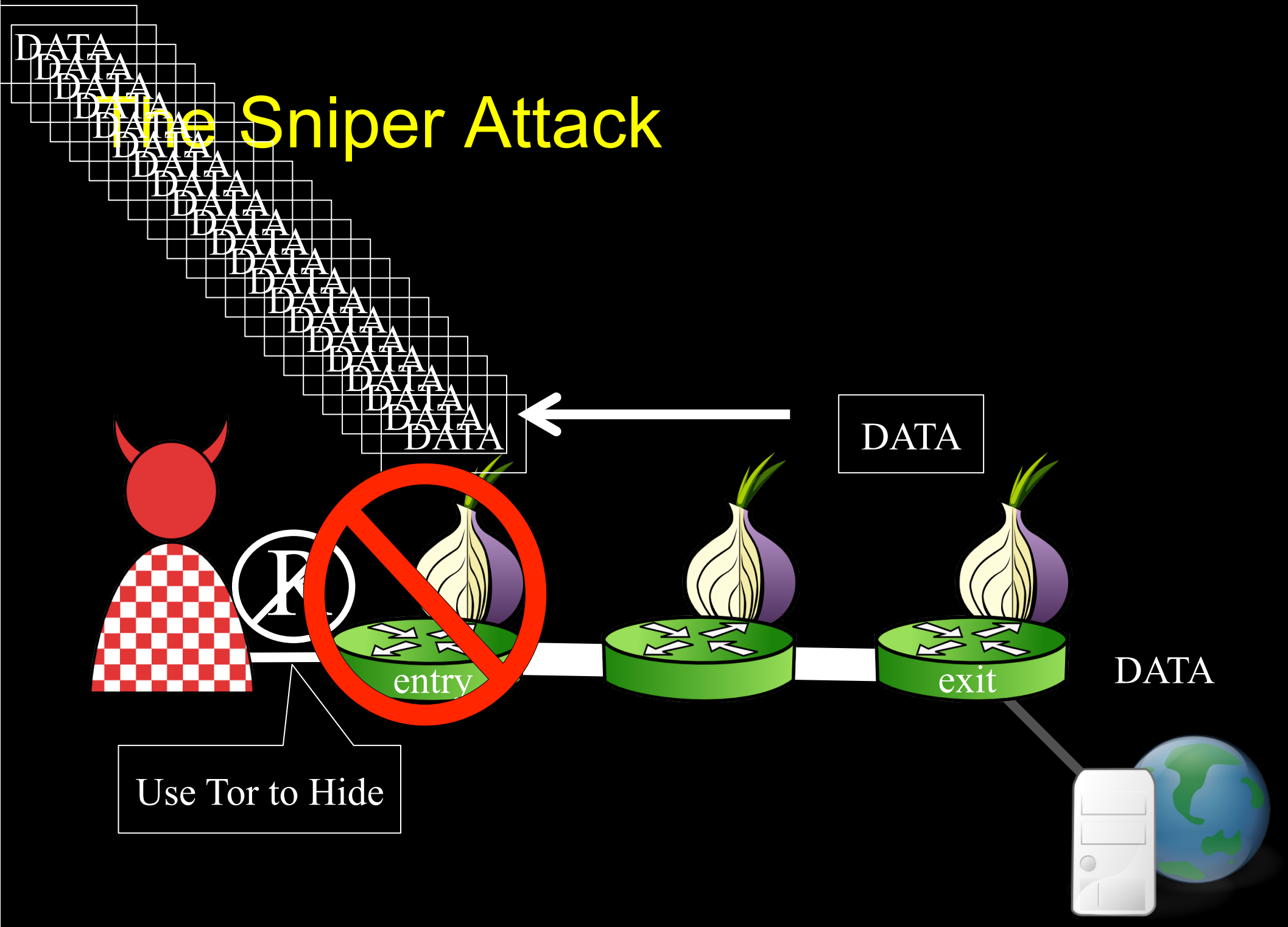
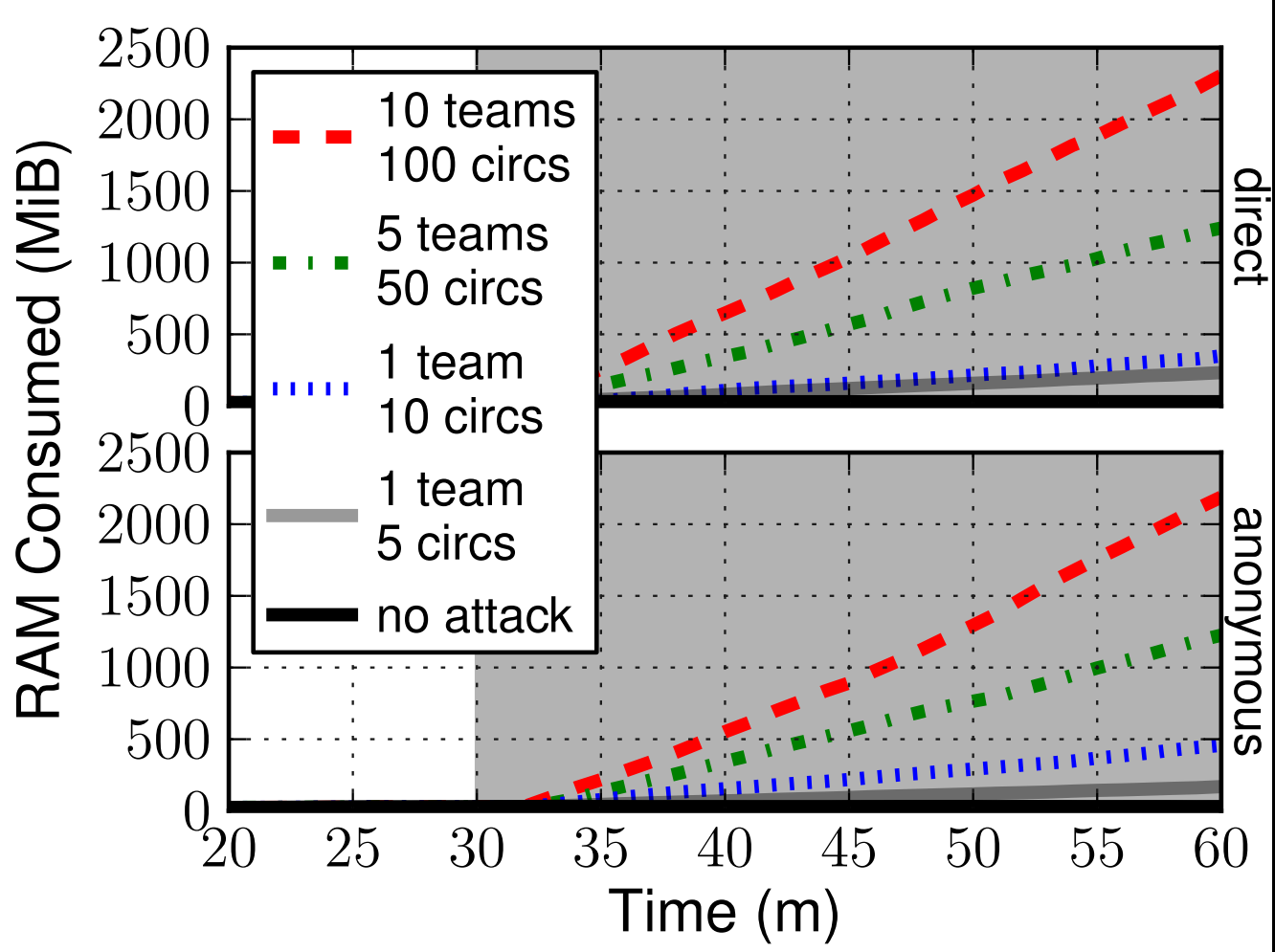
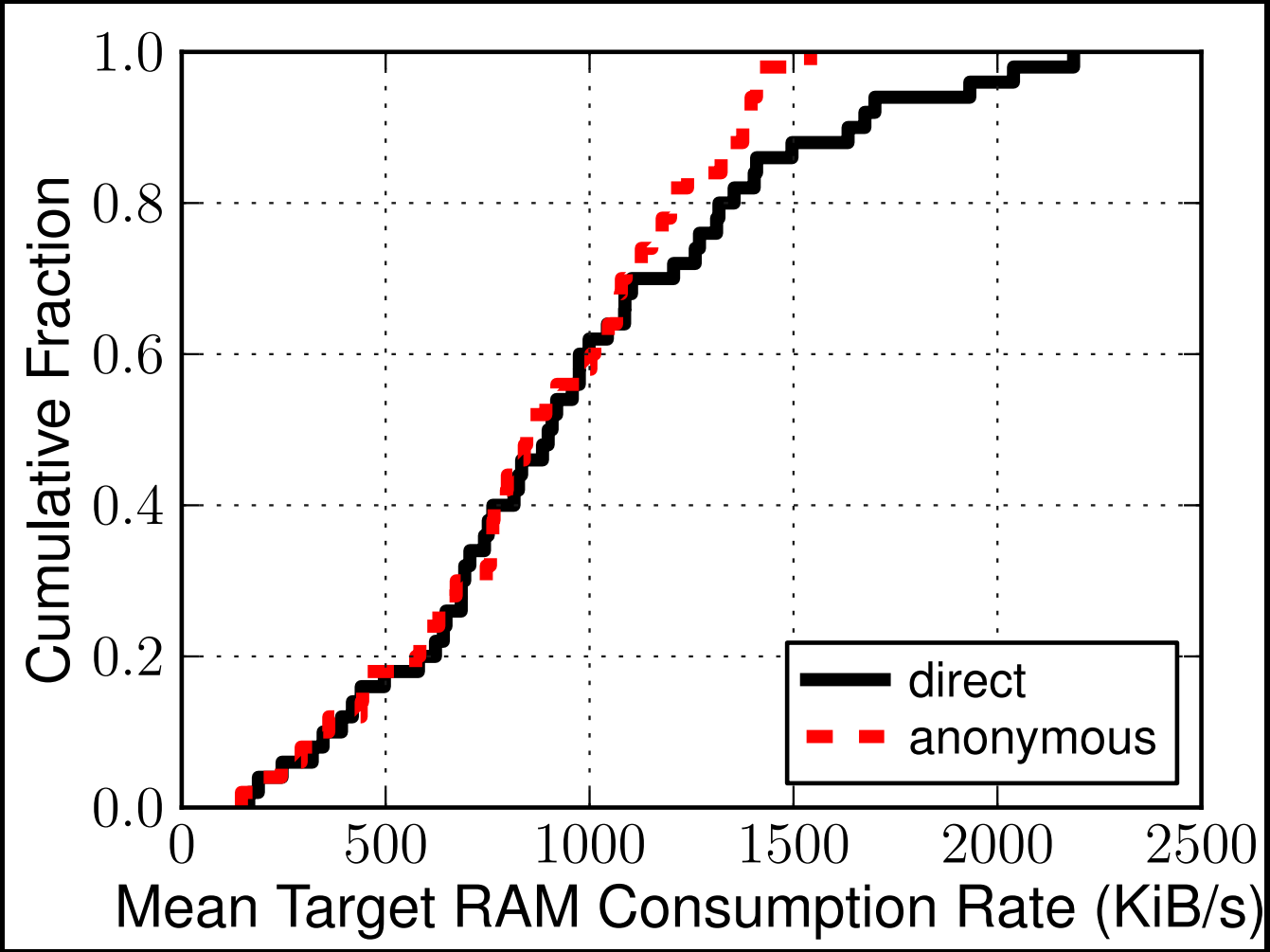


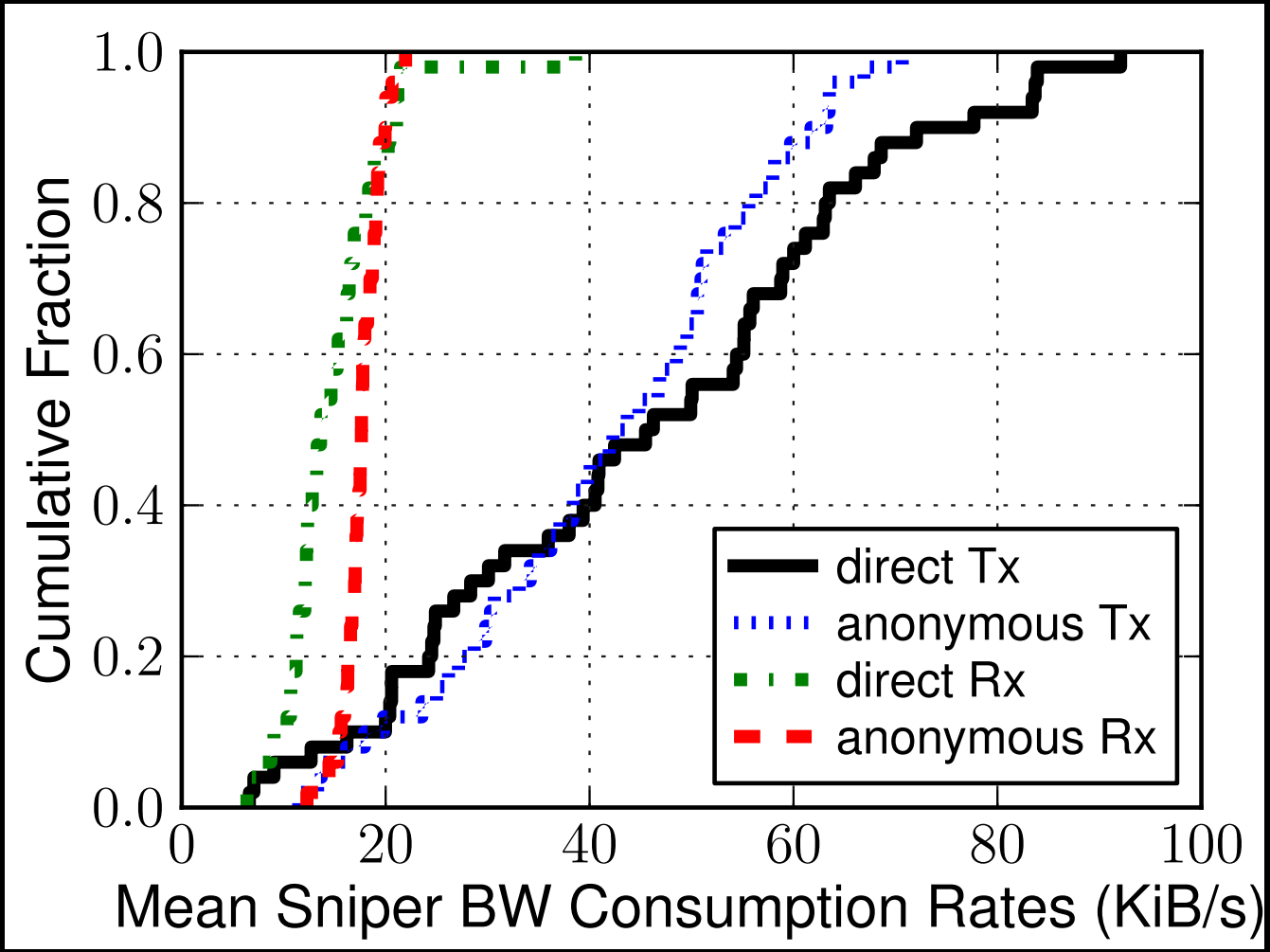
Memory Consumed over Time



Mean RAM Consumed, 50 Relays



Mean BW Consumed, 50 Relays



Speed of Sniper Attack

		Direct		Anonymous	
Relay Groups	**Select %**	**1 GiB**	**8 GiB**	**1 GiB**	**8 GiB**
Top Guard	1.7				
Top 5 Guards	6.5				
Top 20 Guards	19				
Top Exit	3.2				
Top 5 Exits	13				
Top 20 Exits	35				

Path Selection Probability
≈ Network Capacity

Speed of Sniper Attack

		Direct		Anonymous	
Relay Groups	**Select %**	**1 GiB**	**8 GiB**	**1 GiB**	**8 GiB**
Top Guard	1.7	0:01	0:18	0:02	0:14
Top 5 Guards	6.5	0:08	1:03	0:12	1:37
Top 20 Guards	19	0:45	5:58	1:07	8:56
Top Exit	3.2	0:01	0:08	0:01	0:12
Top 5 Exits	13	0:05	0:37	0:07	0:57
Top 20 Exits	35	0:29	3:50	0:44	5:52

Time (hours:minutes) to Consume RAM

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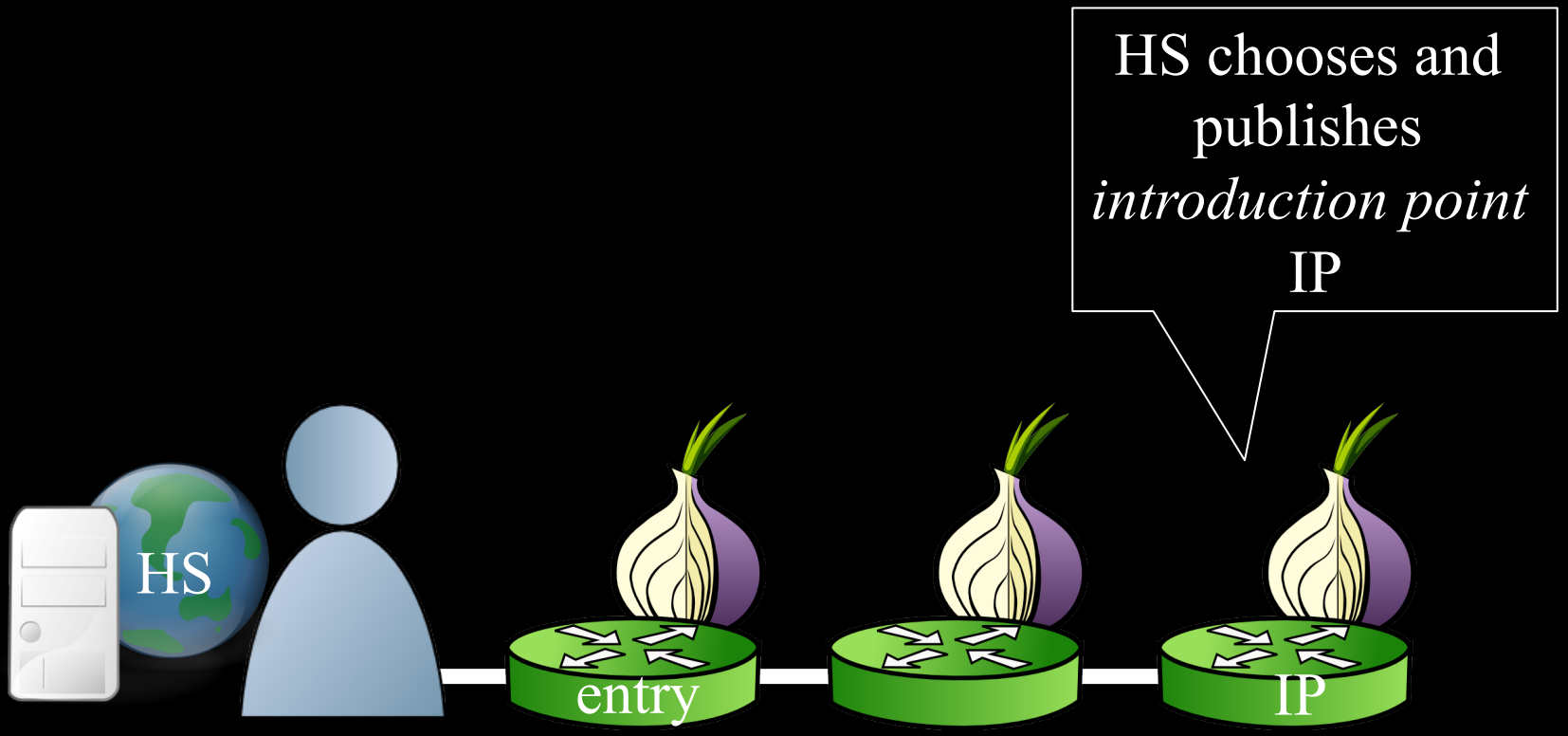
Hidden Services

Hidden Services



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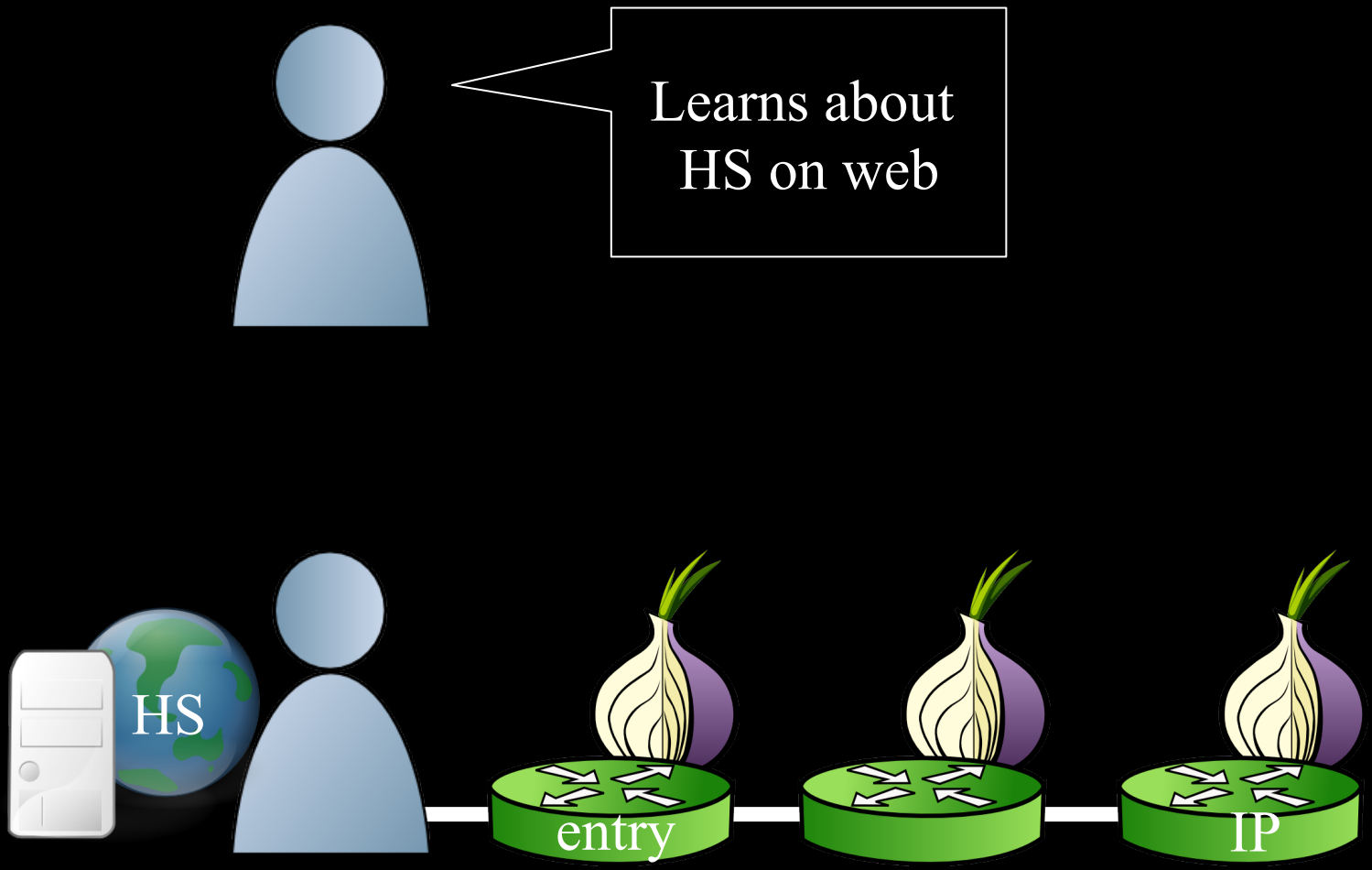

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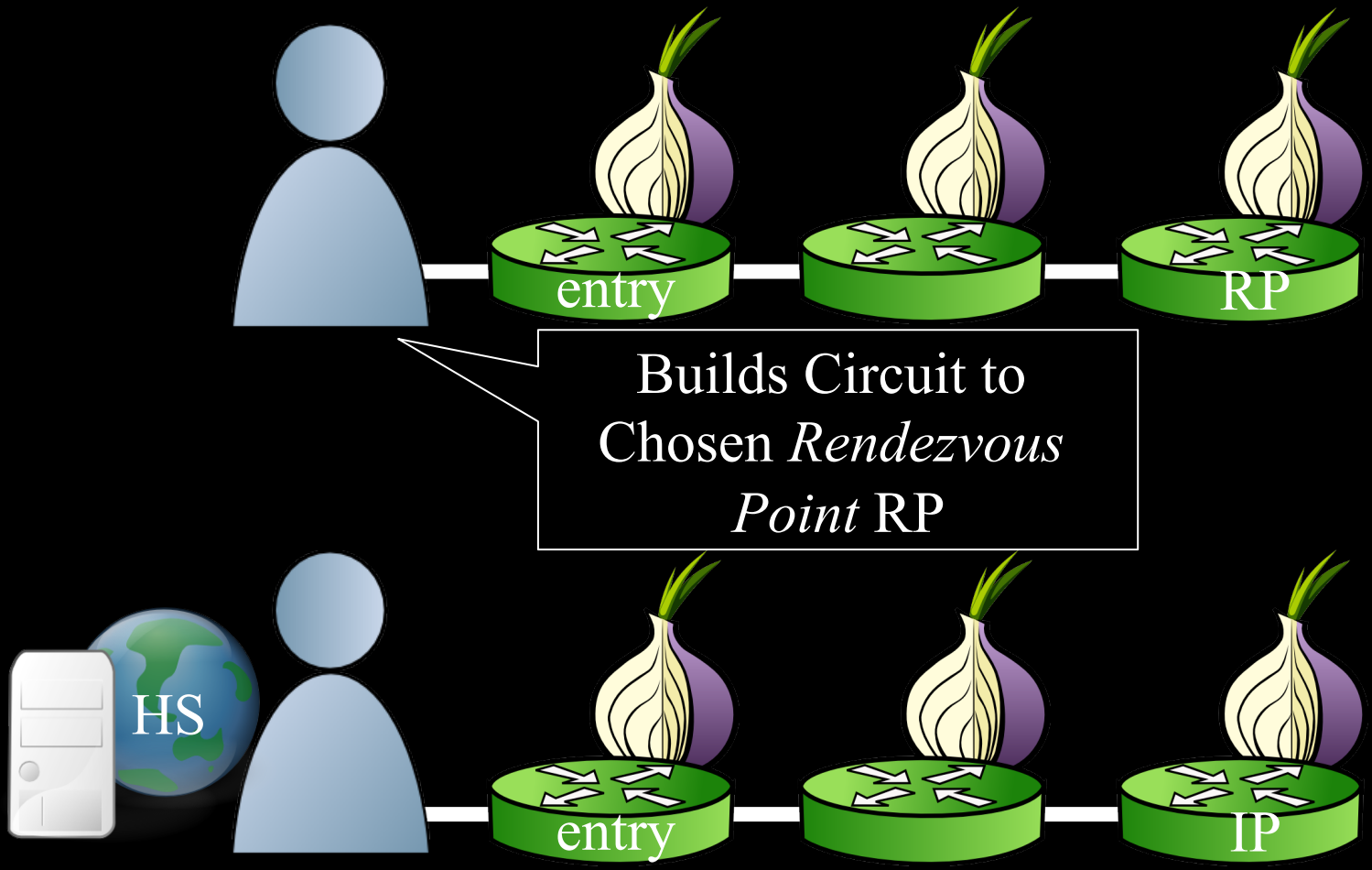

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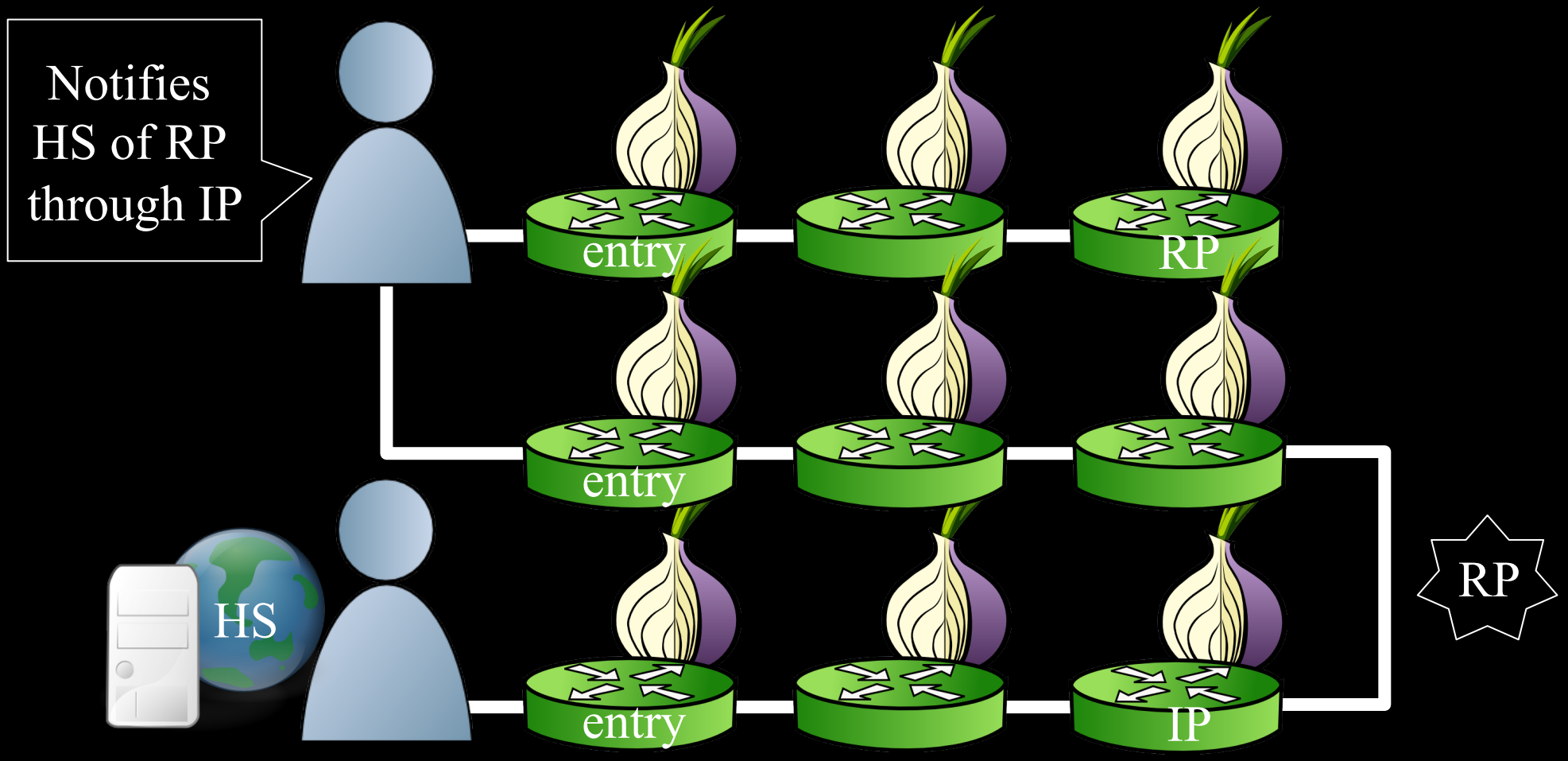

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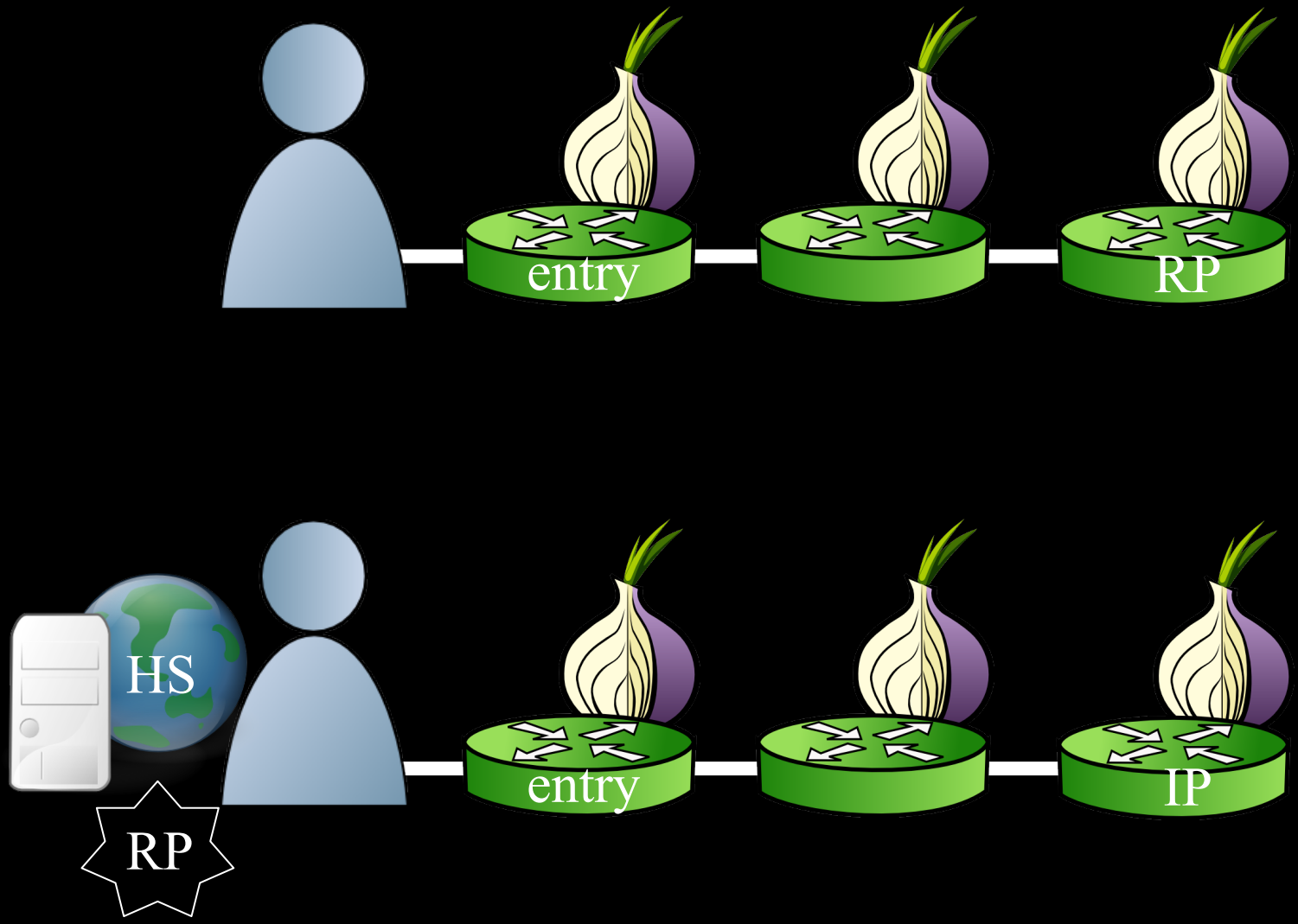

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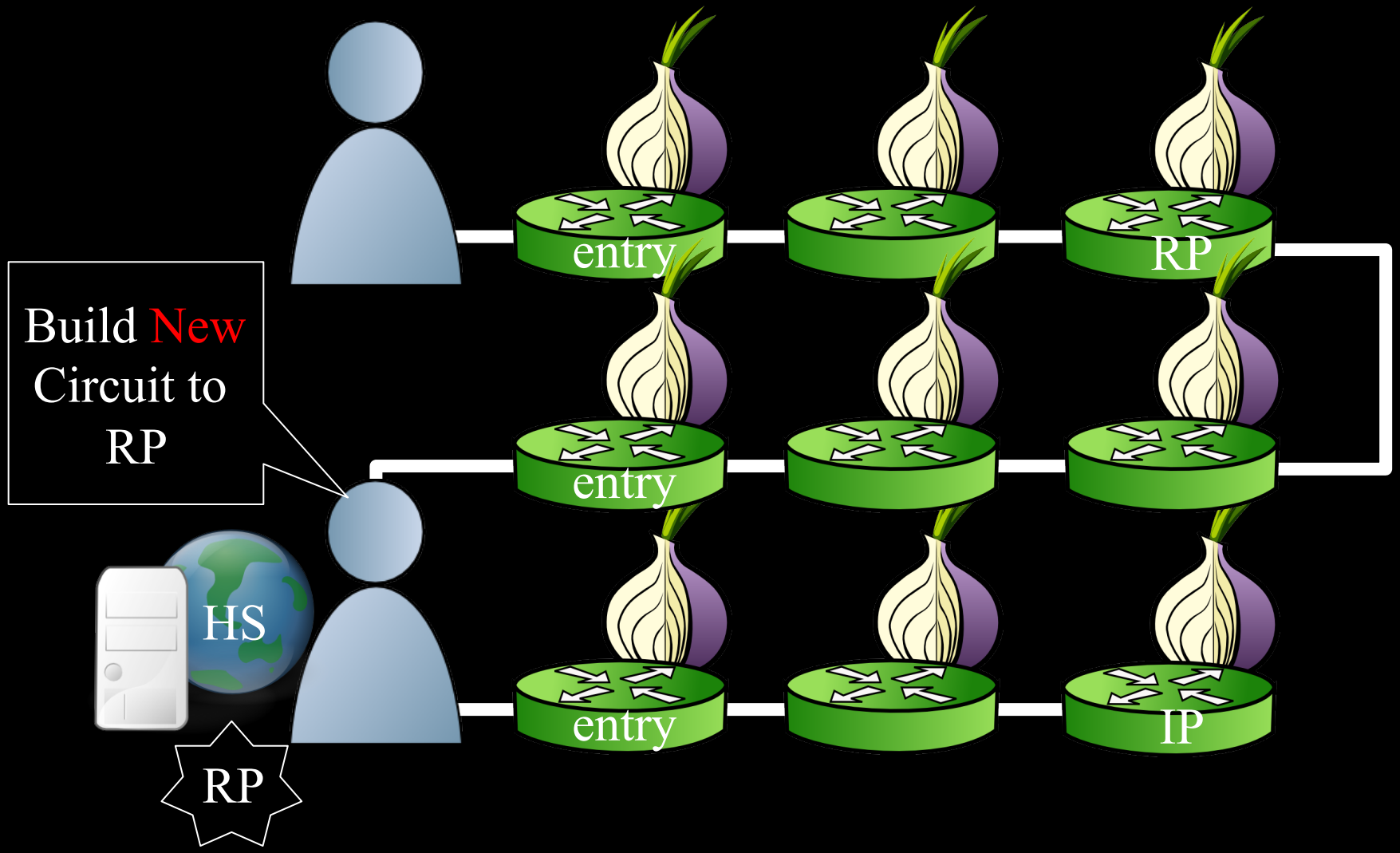

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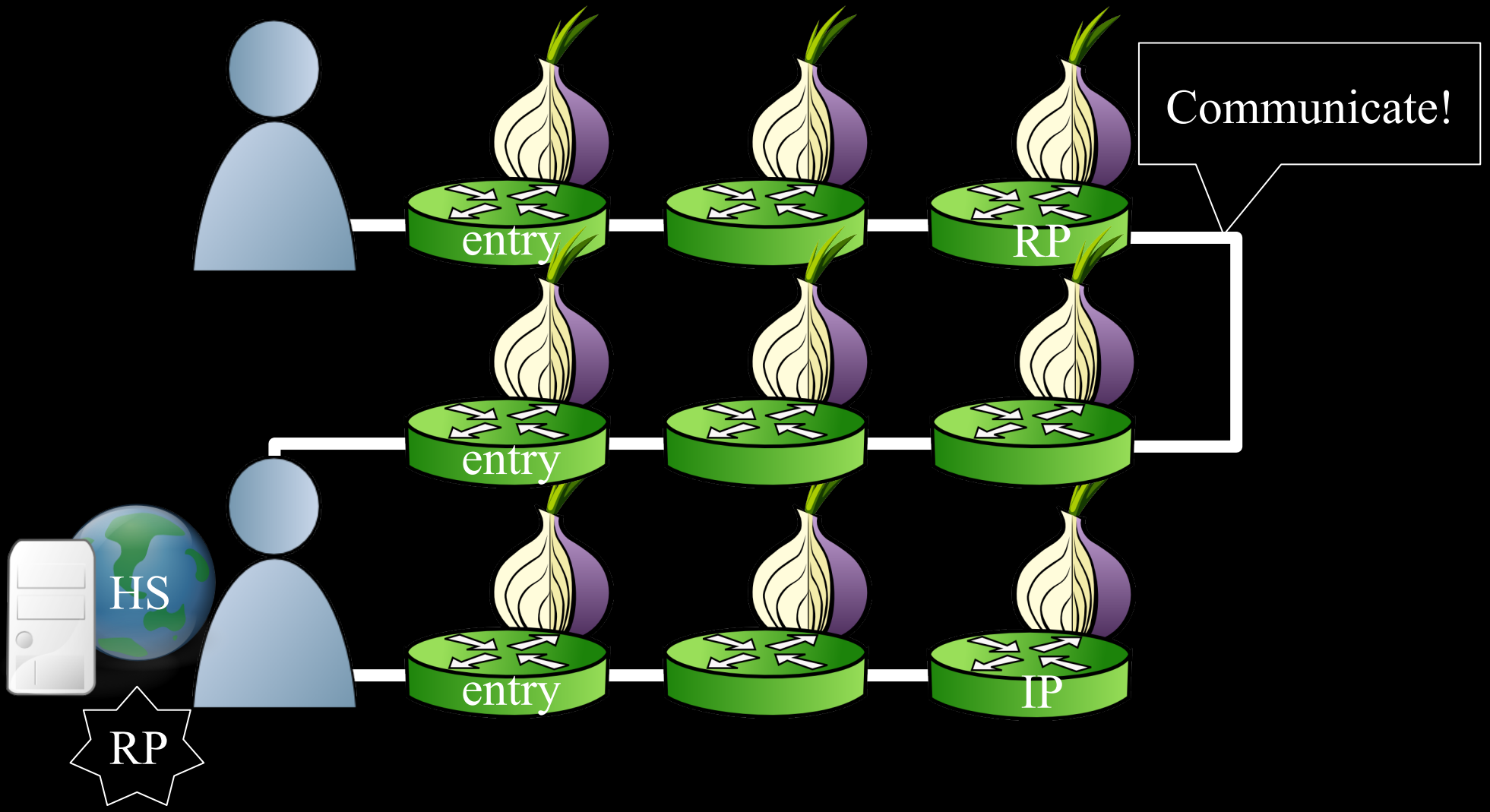
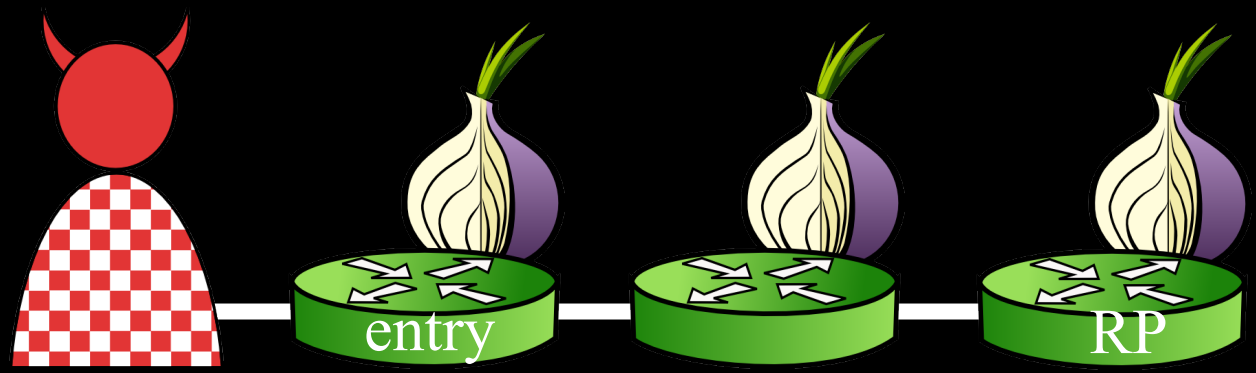


Deanonymizing Hidden Services



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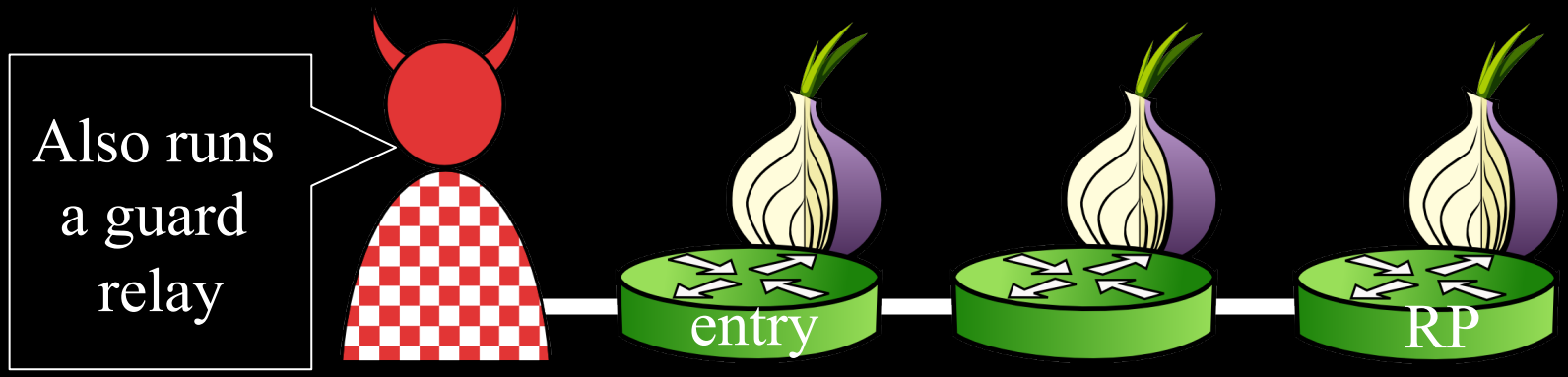

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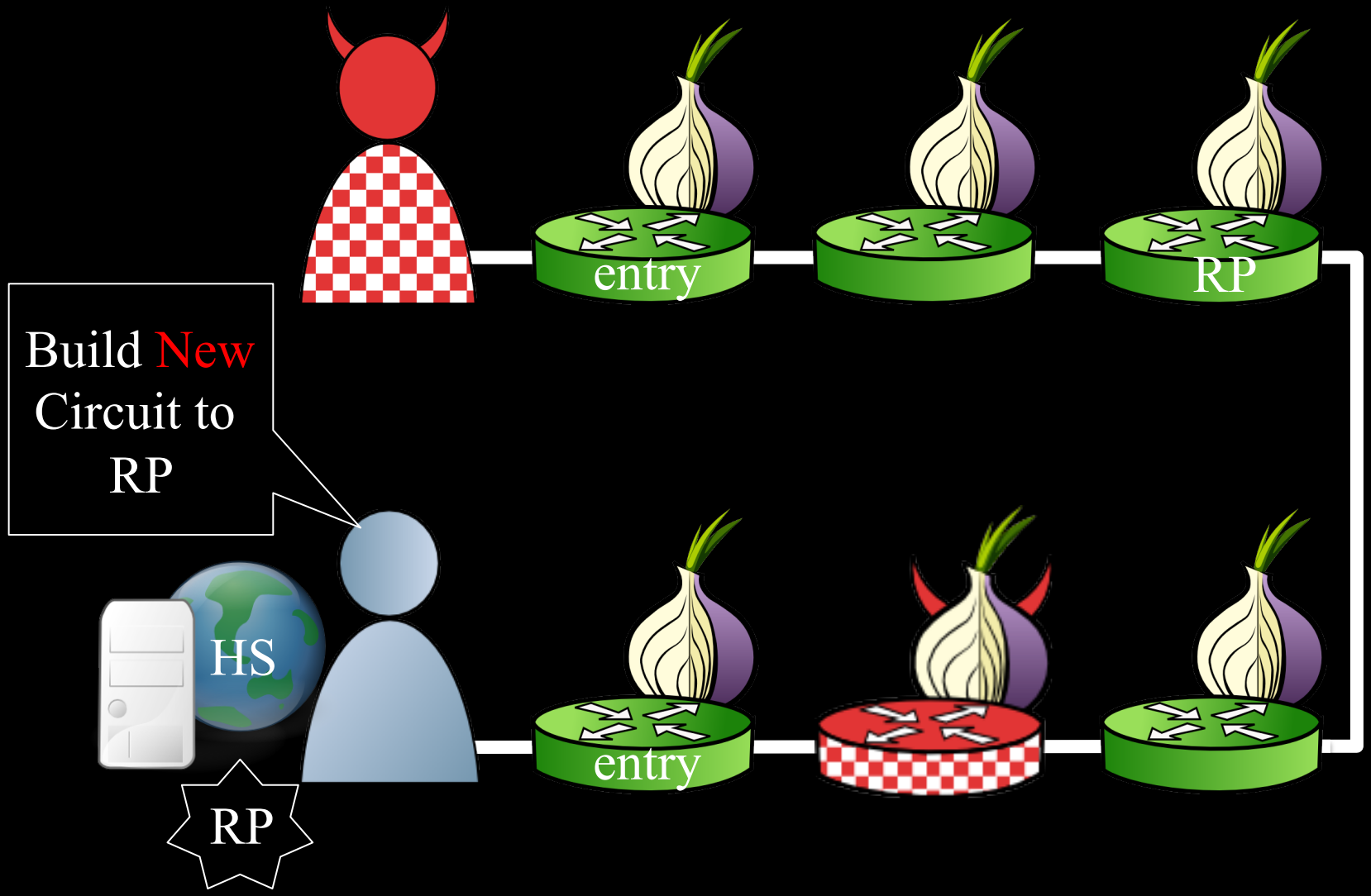

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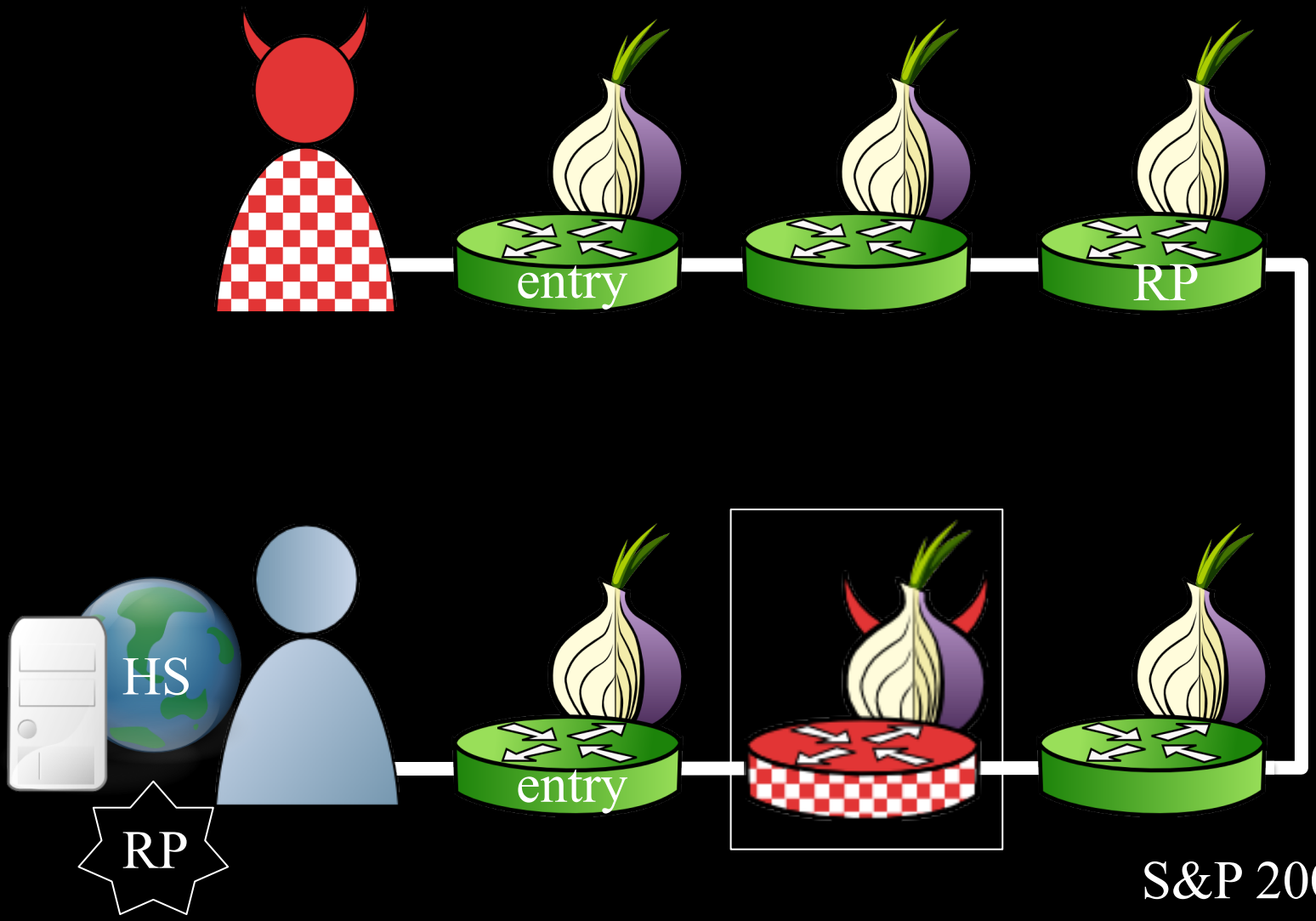

S&P 2006, S&P 2013

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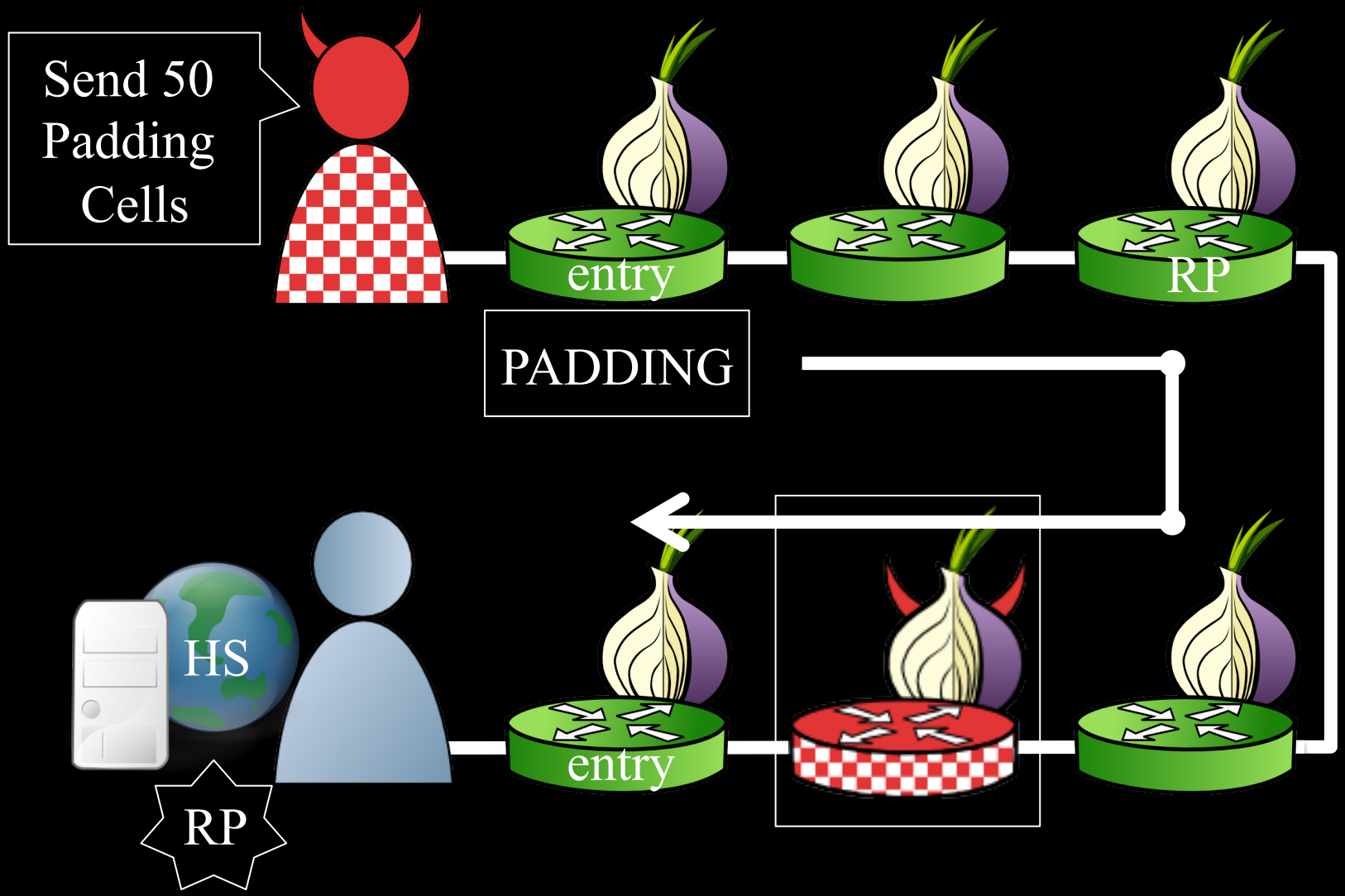
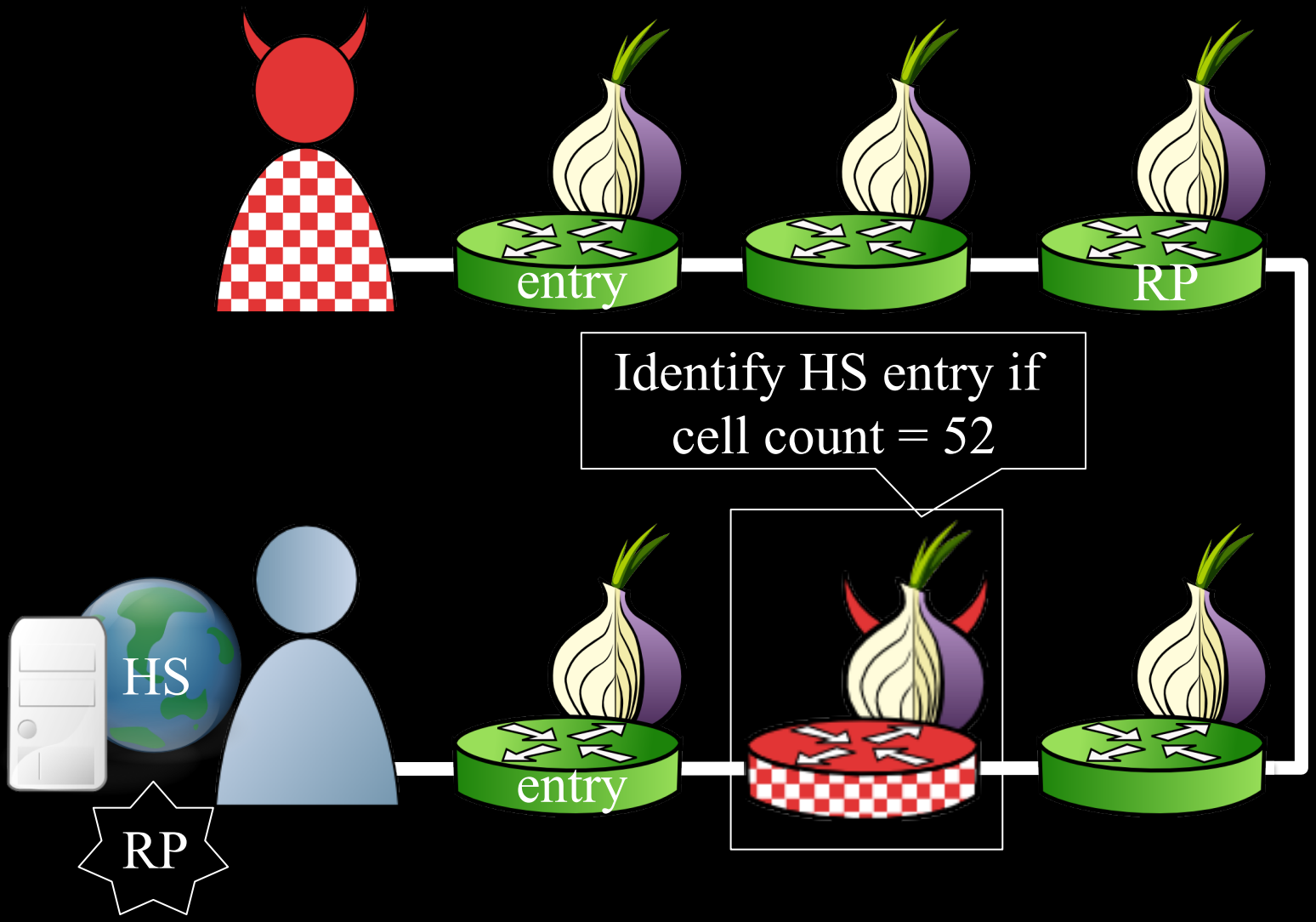


S&P 2013

Deanonymizing Hidden Services



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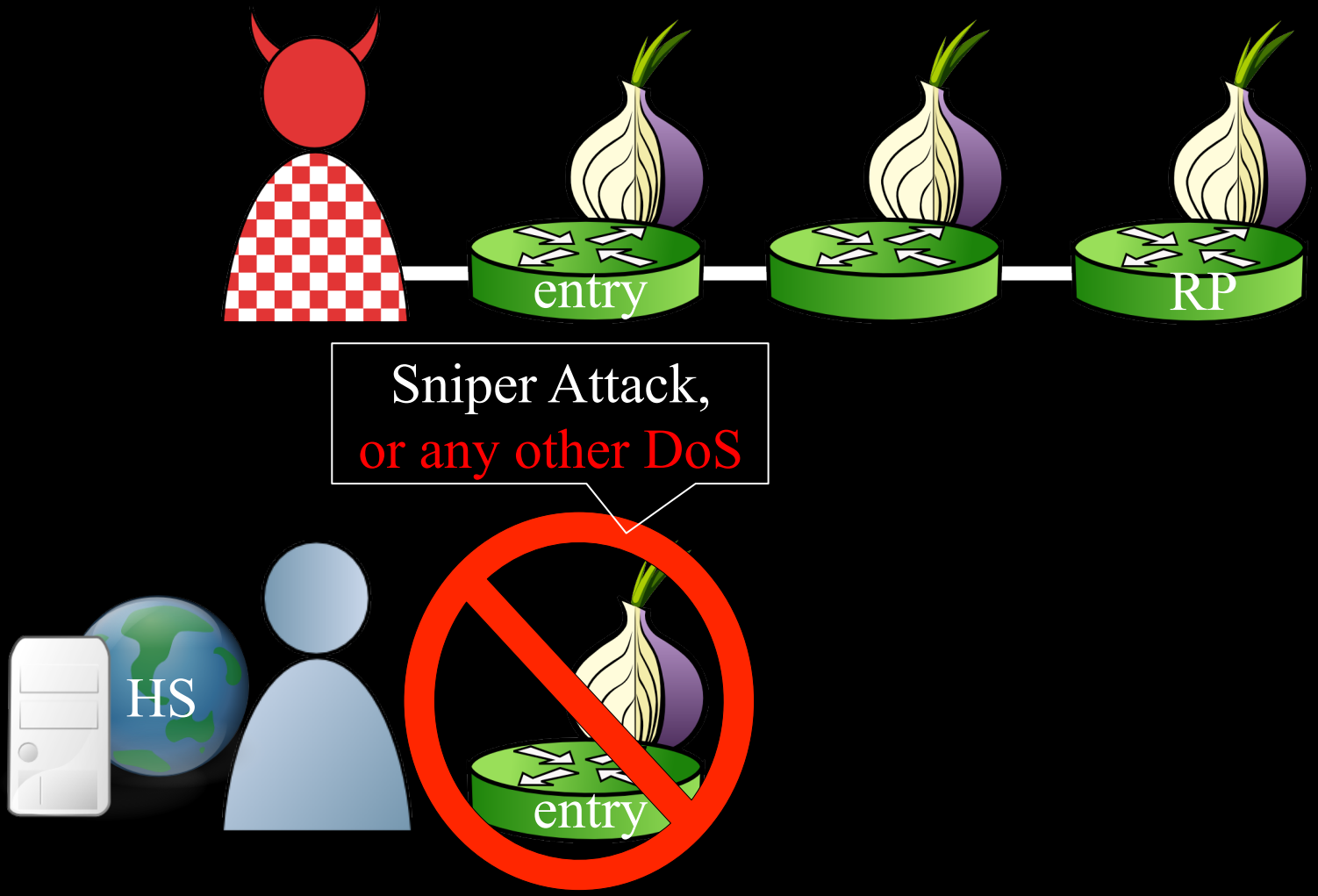

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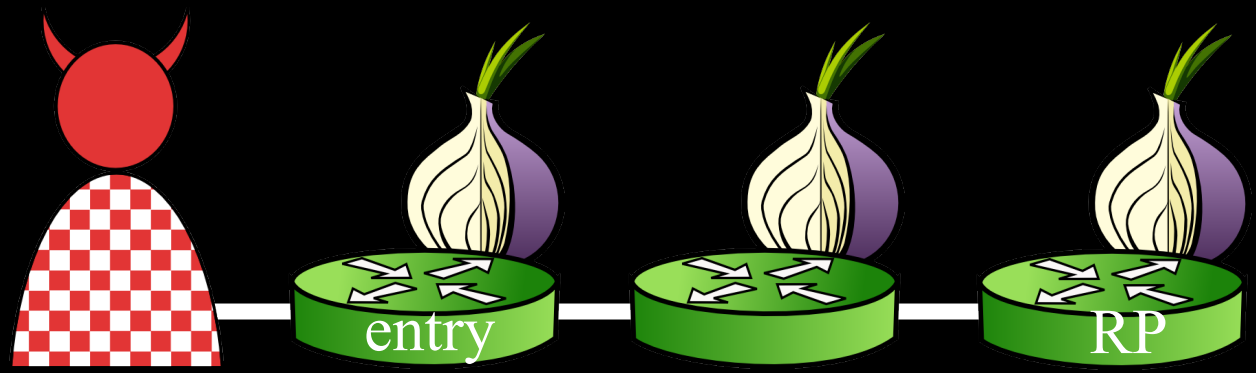

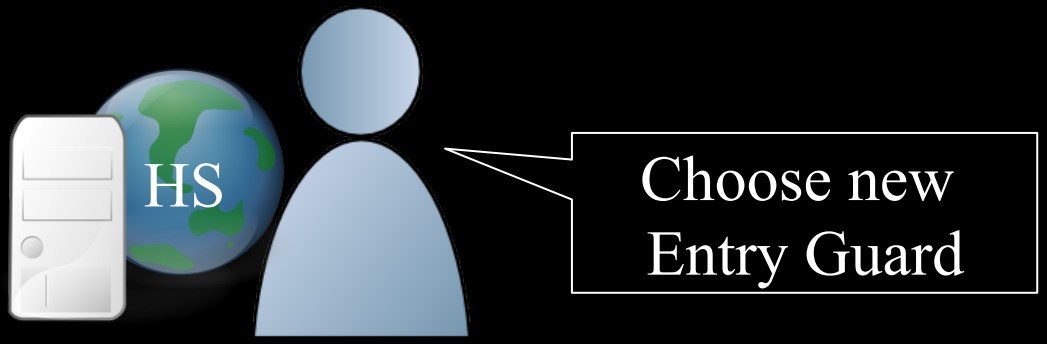

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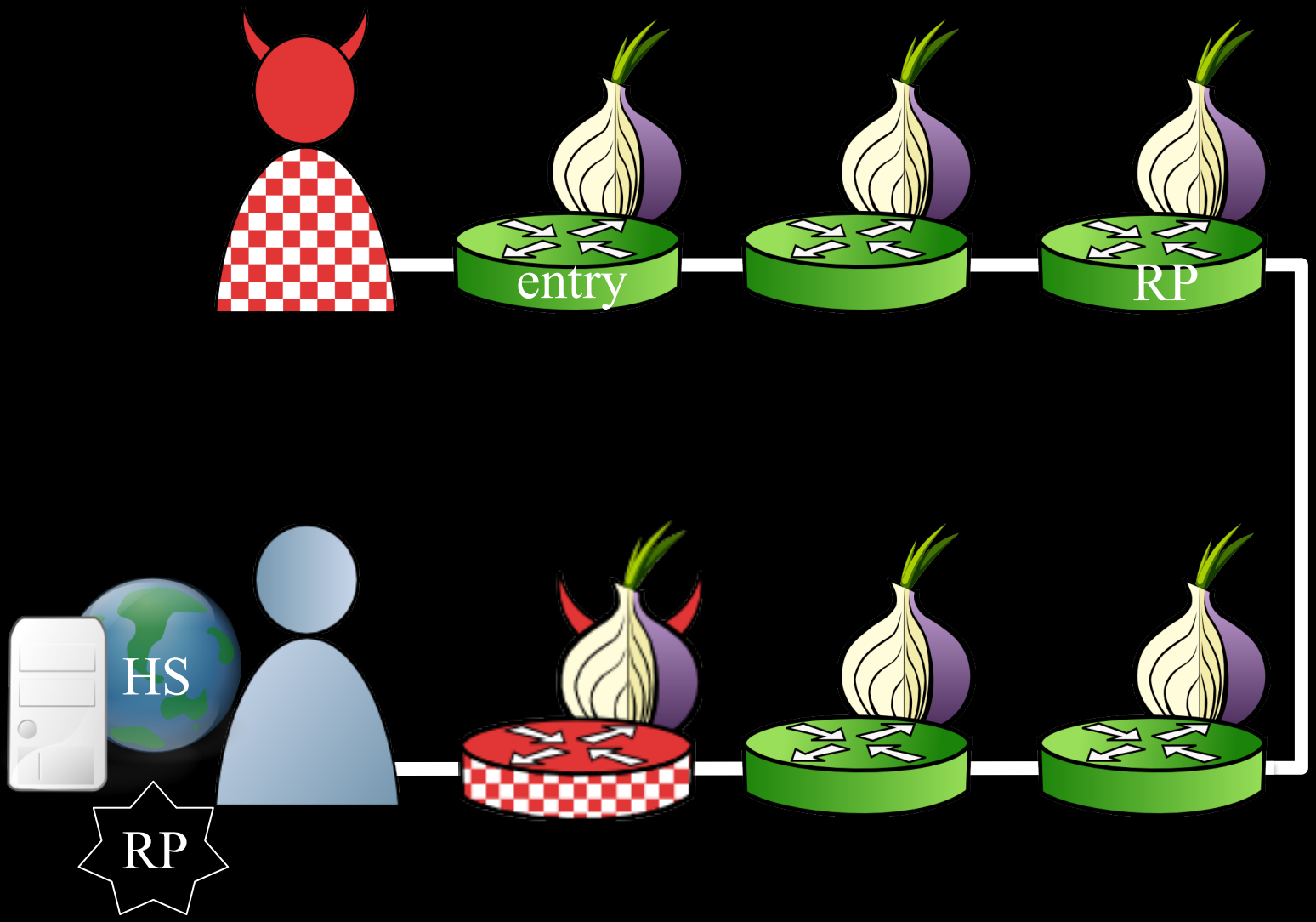

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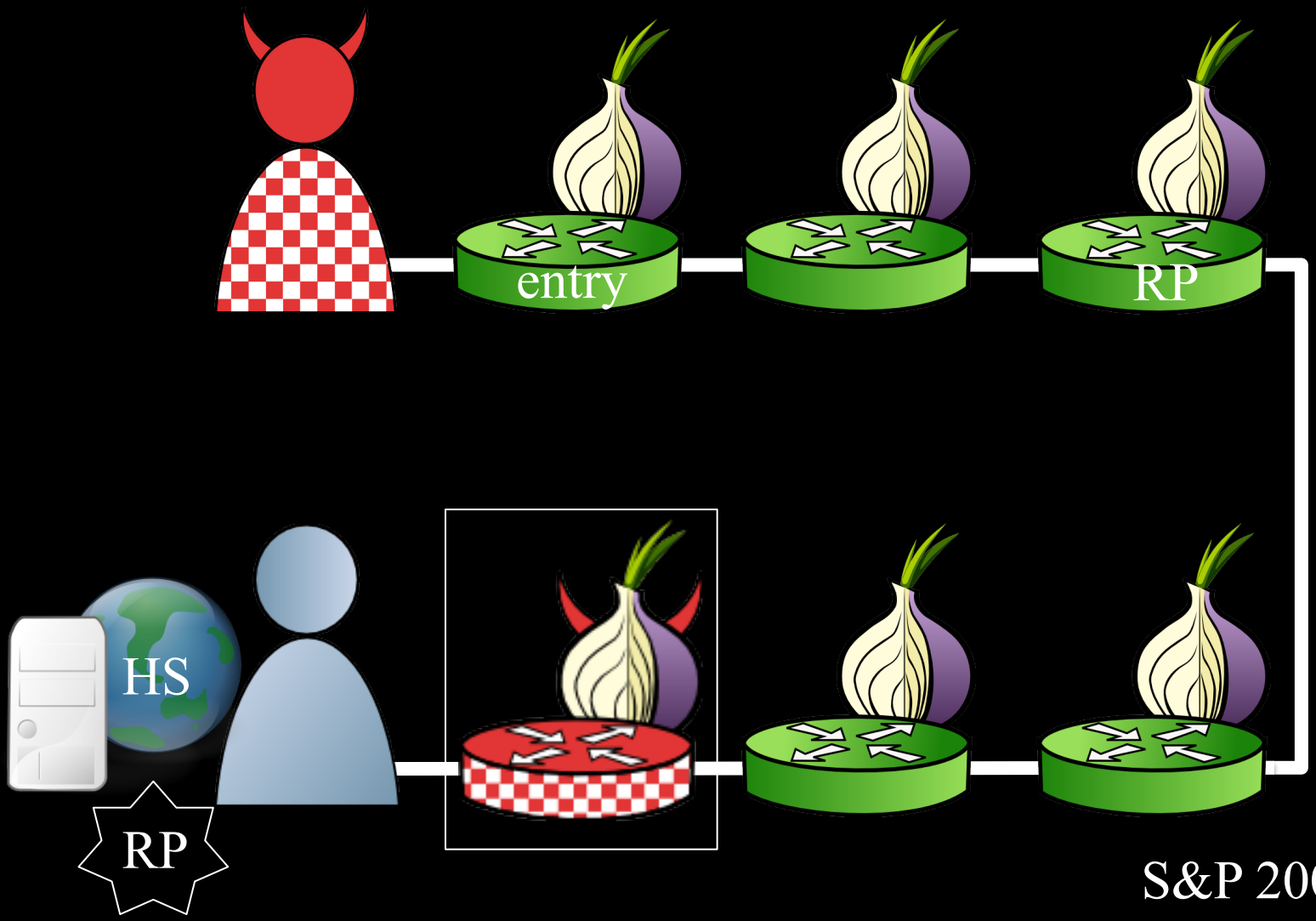

S&P 2006, S&P 2013

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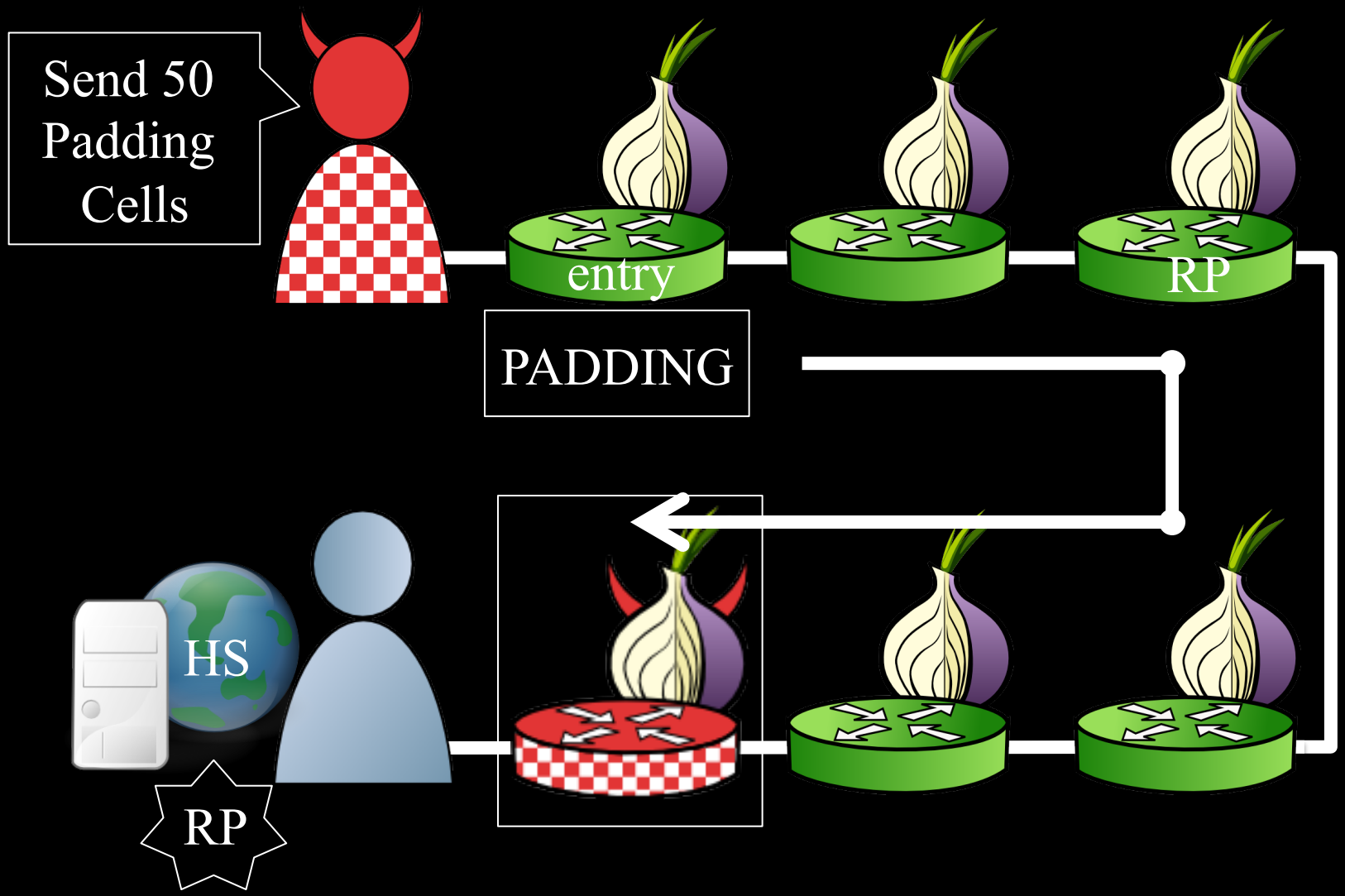

S&P 2013

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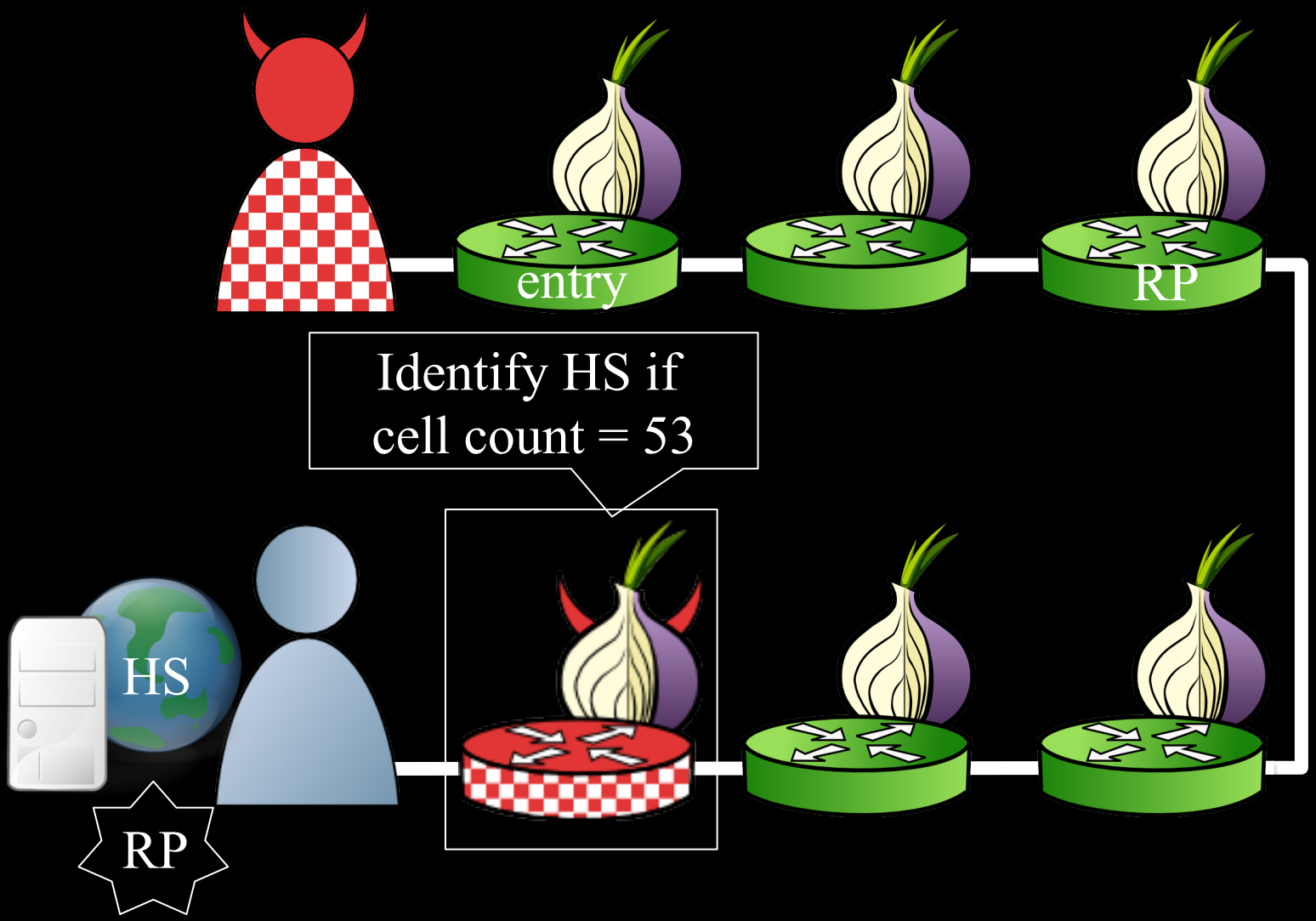

S&P 2013

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Countermeasures

- Sniper Attack Defenses
  - Authenticated SENDMEs
  - Queue Length Limit
  - Adaptive Circuit Killer
- Deanonymization Defenses
  - Entry-guard Rate-limiting
  - Middle Guards

Questions?

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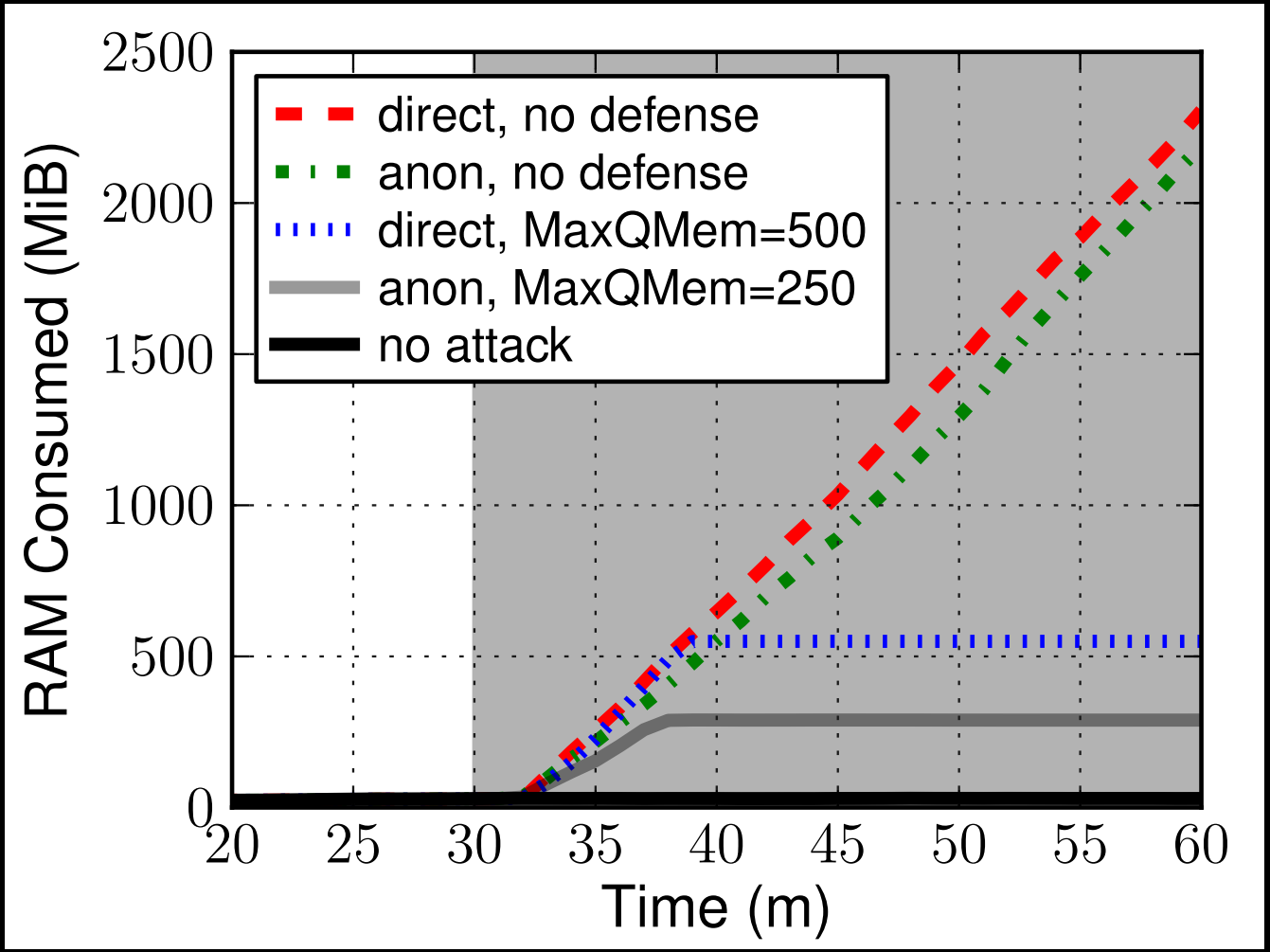
think like an adversary

Speed of Deanonymization

Guard BW (MiB/s)	Guard Probability (%)	Average # Rounds	Average # Sniped	Average Time (h) 1 GiB	Average Time (h) 8 GiB
8.41	0.48	66	133	46	279
16.65	0.97	39	79	23	149
31.65	1.9	24	48	13	84
66.04	3.8	13	26	6	44
96.61	5.4	9	19	5	31

1 GiB/s Relay Can Deanonymize HS in about a day

Circuit Killer Defense



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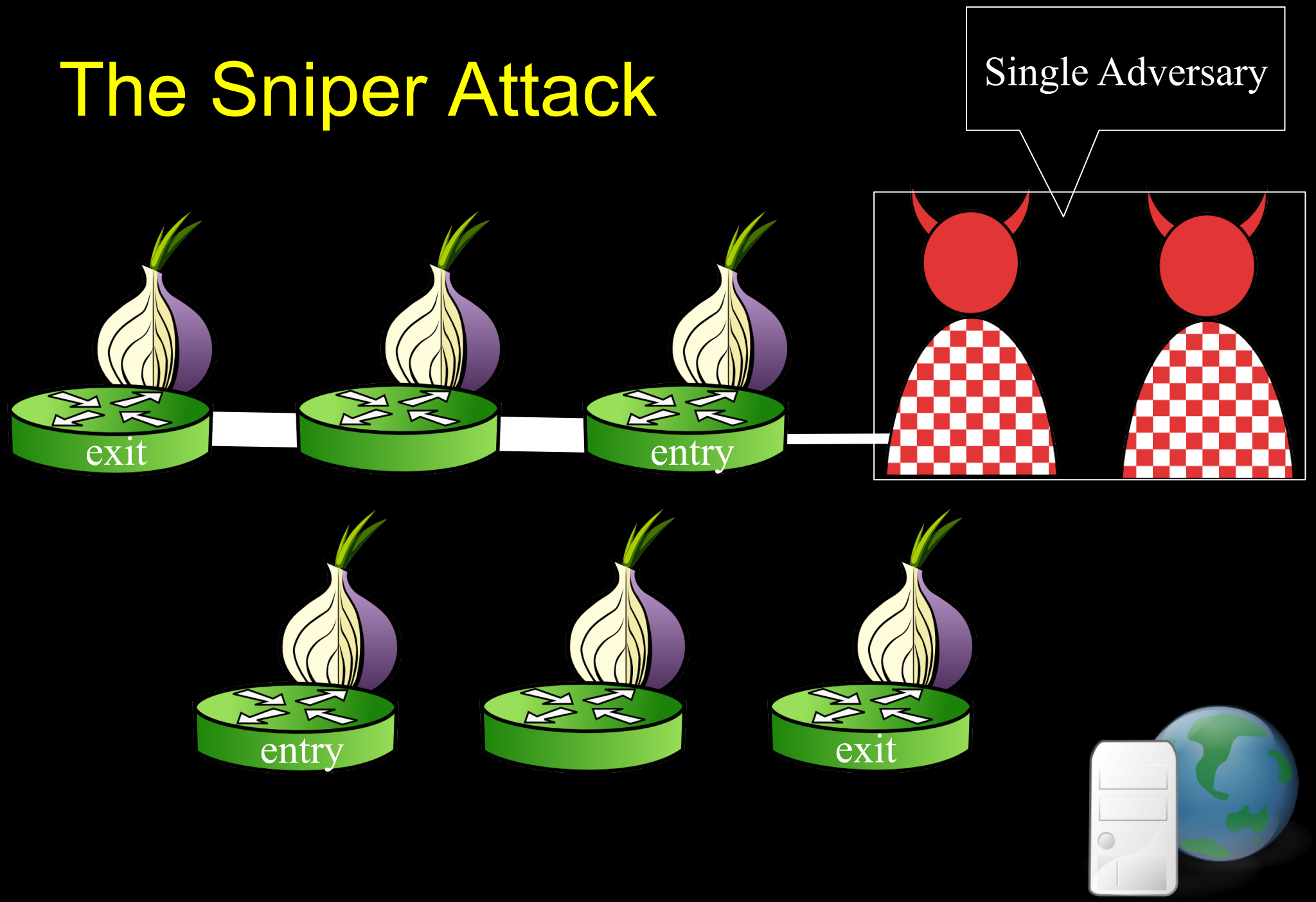

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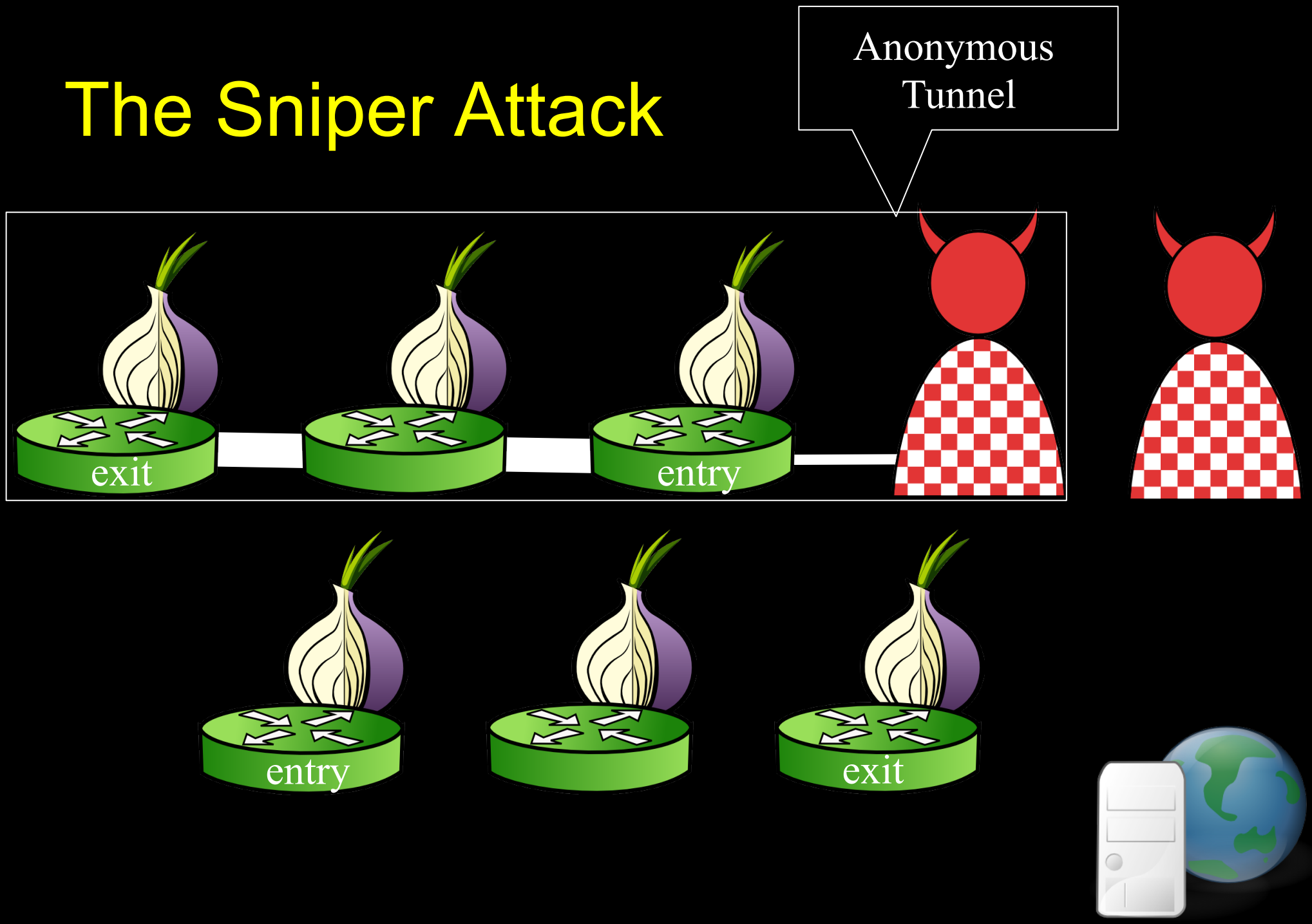
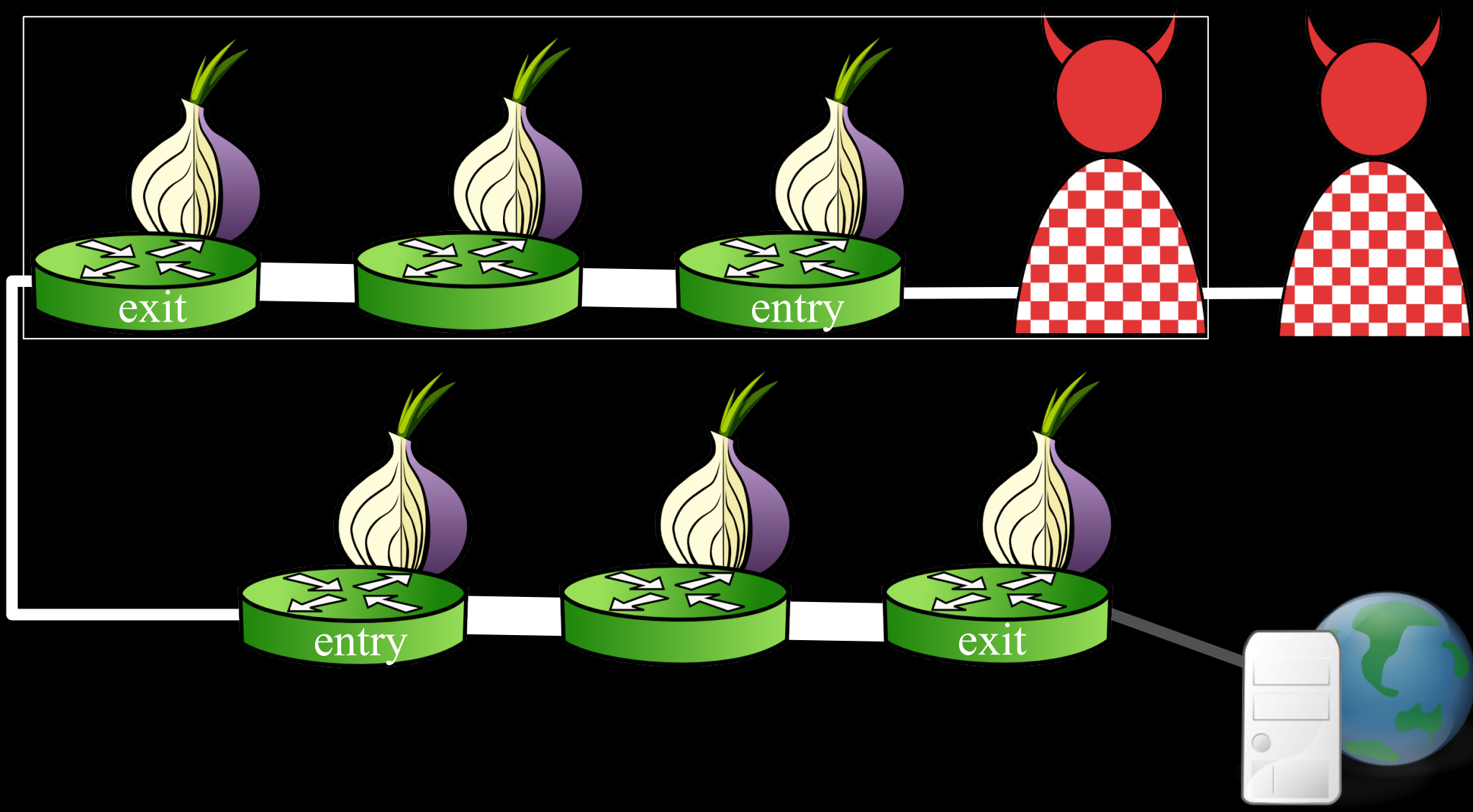


The Sniper Attack



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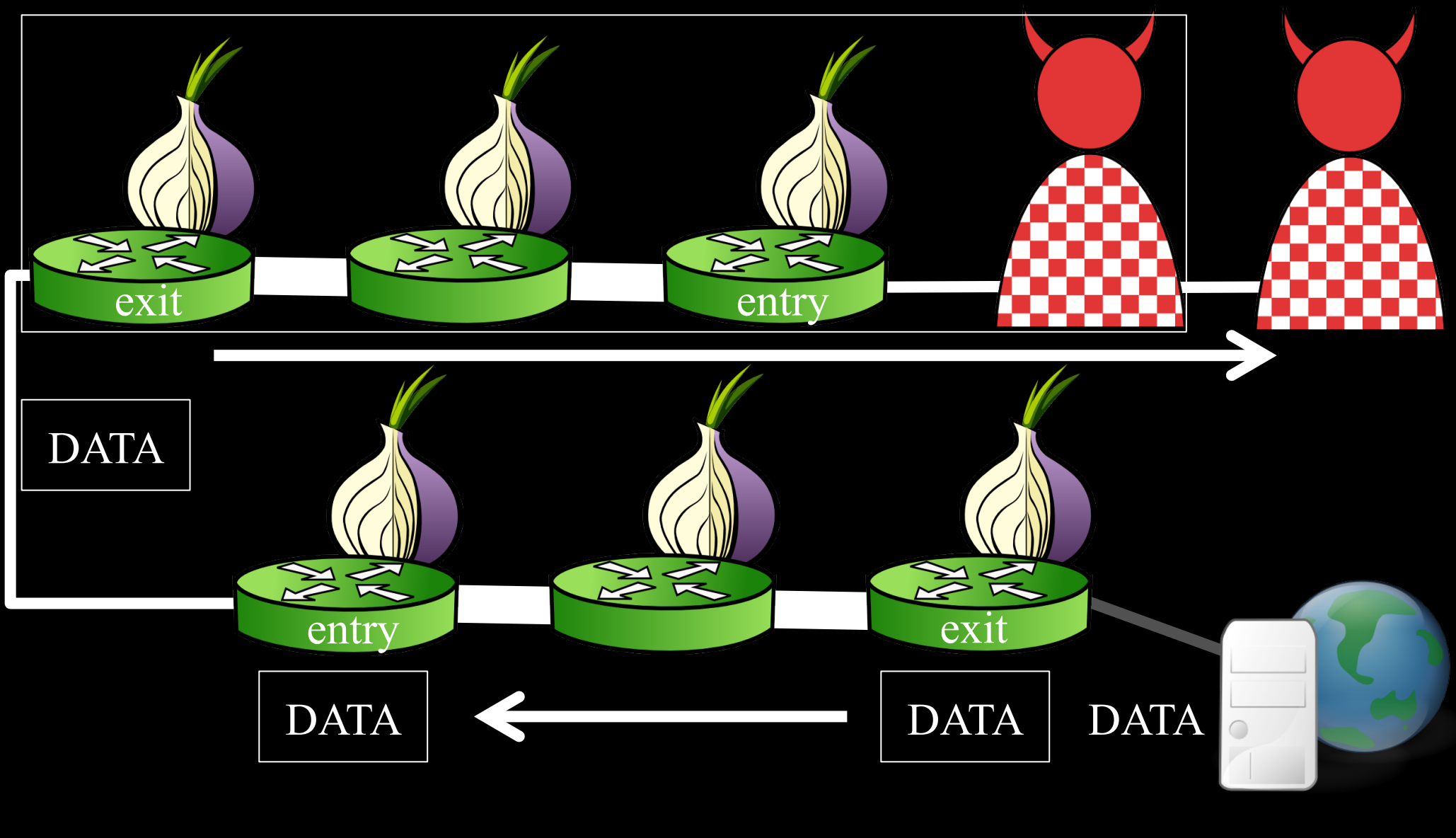

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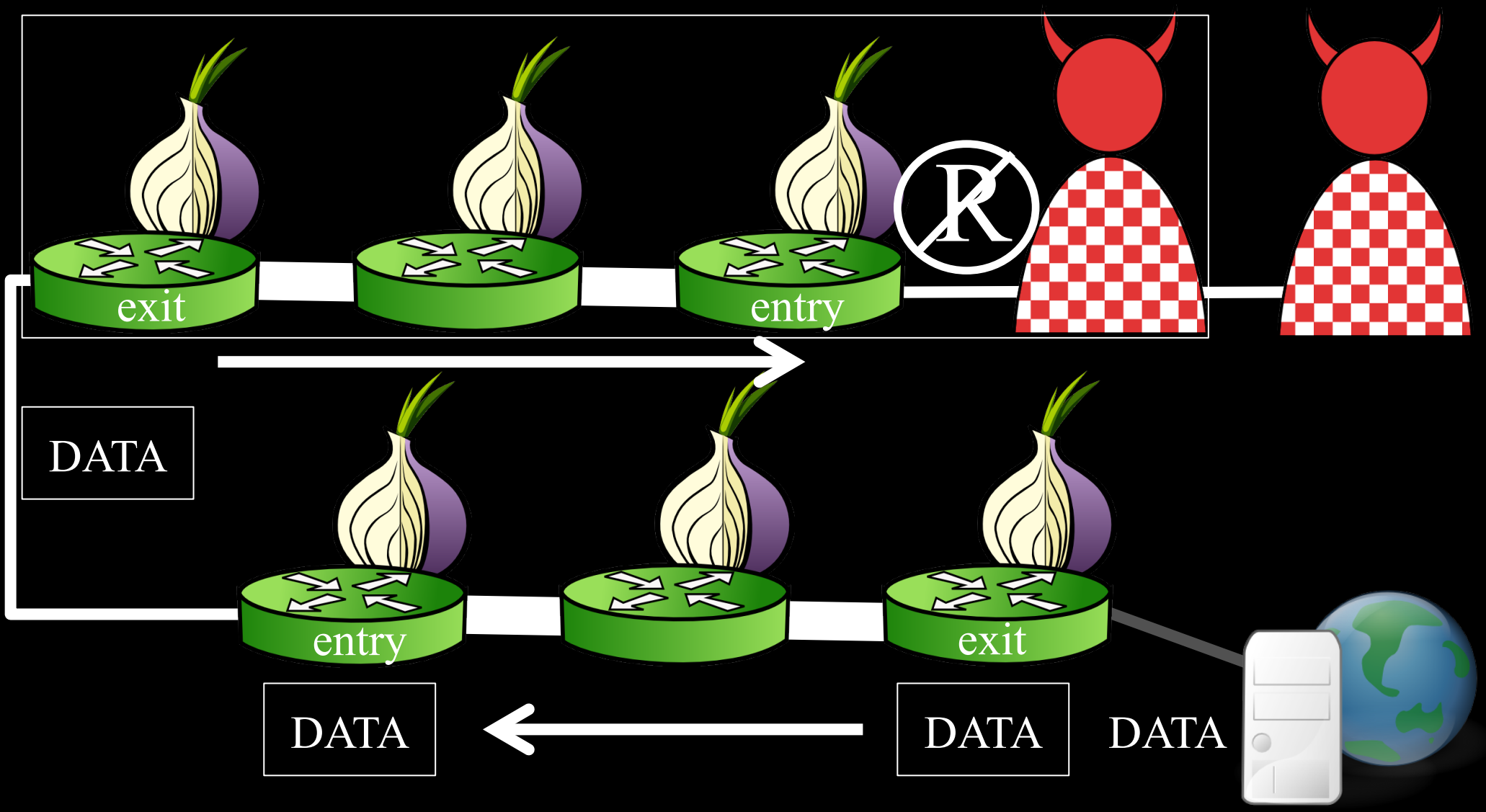

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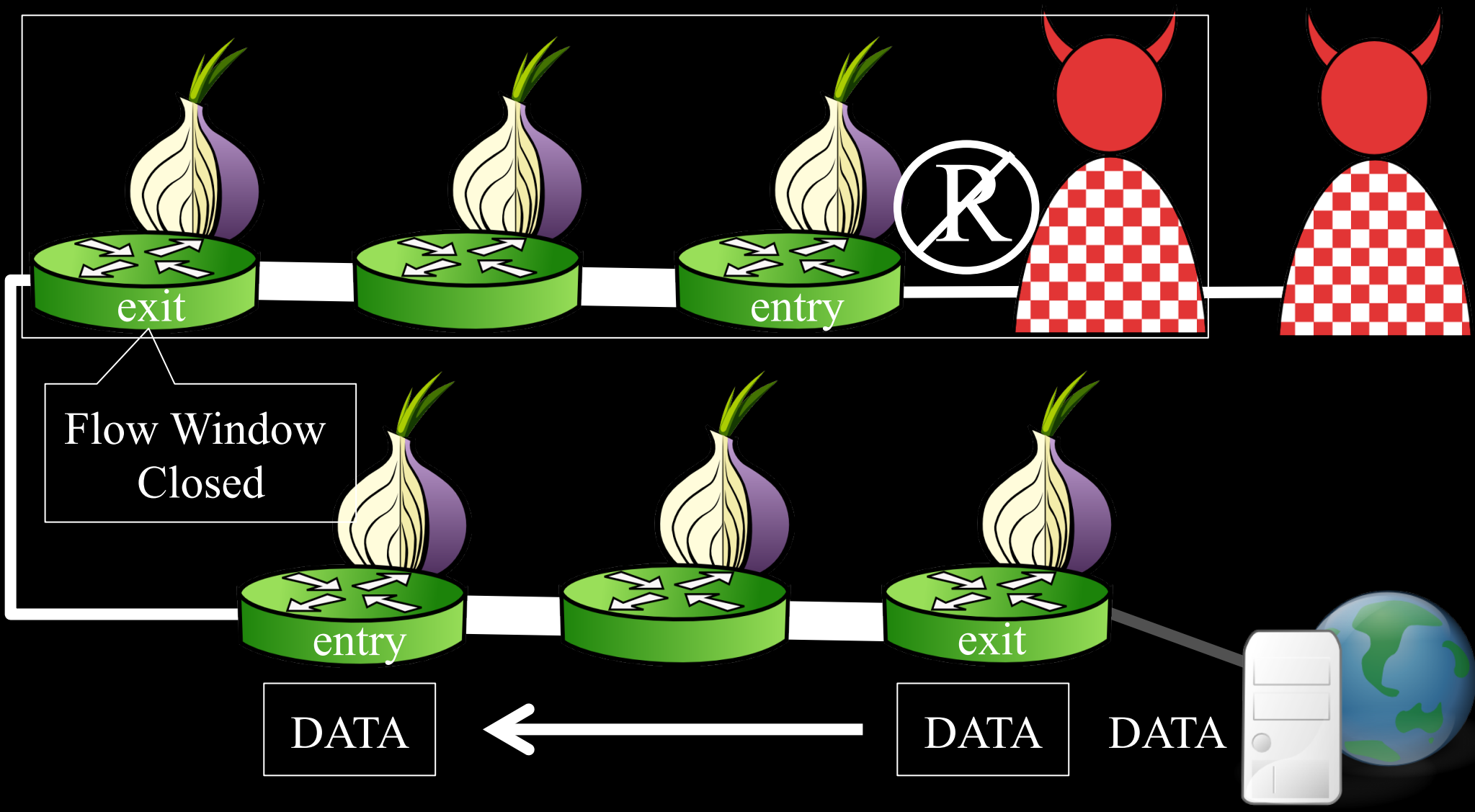

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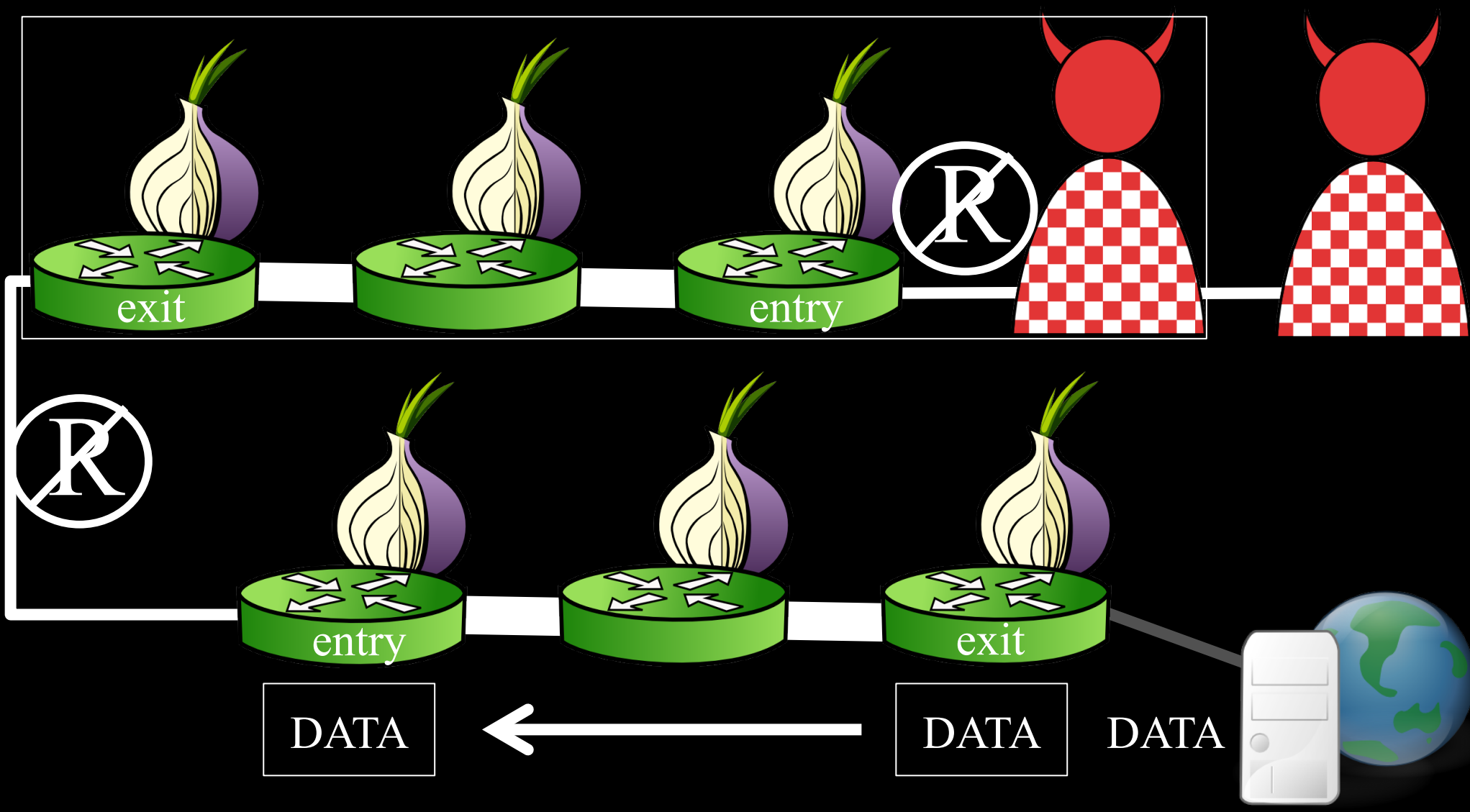

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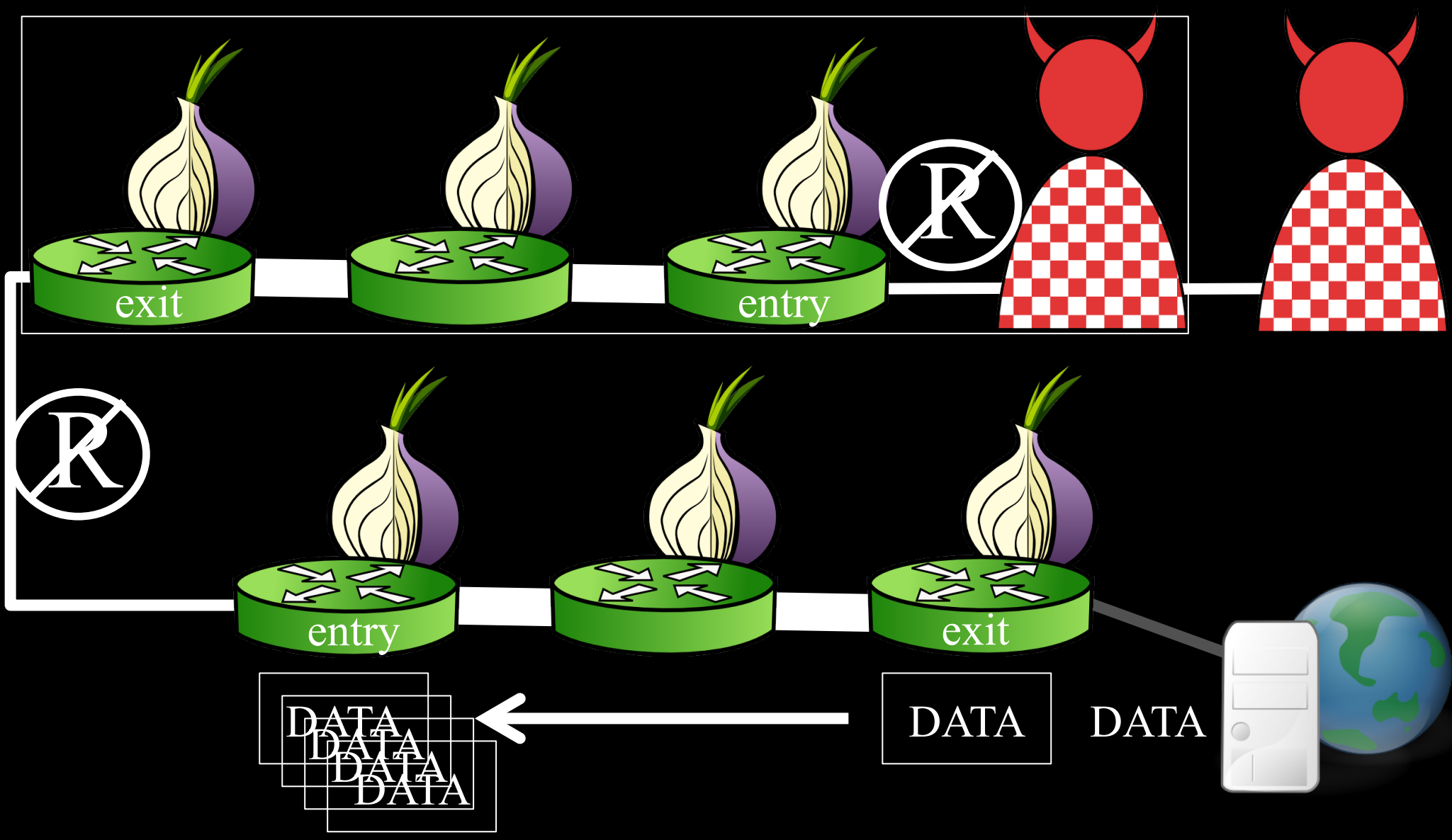

The Sniper Attack