MirageFlow:

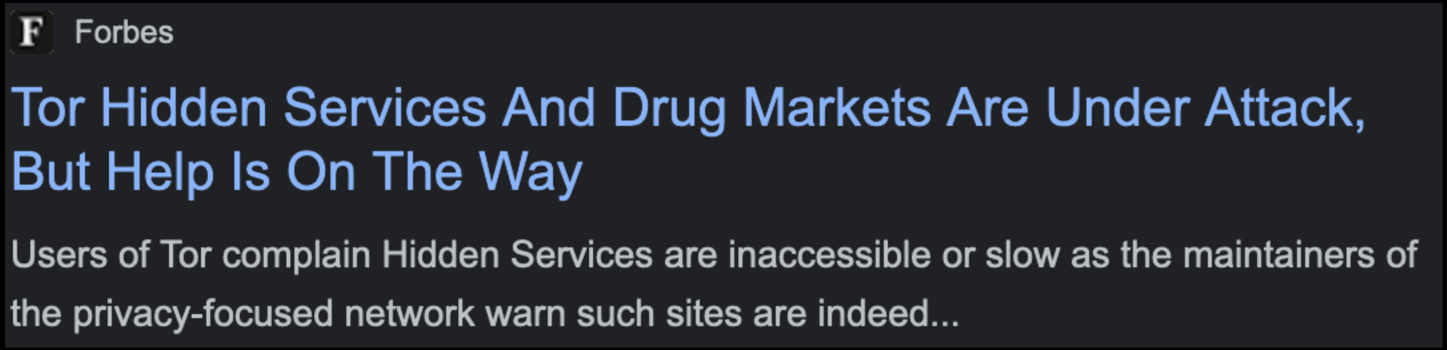
A New Bandwidth Inflation Attack on Tor

Christoph Sendner[1], Jasper Stang[1], Alexandra Dmitrienko[1], Raveen Wijewickrama[2], Murtuza Jadliwala[2]

[1]University of Würzburg, [2]University of Texas at San Antonio

NDSS
SYMPOSIUM/2024

Tor in the News



Forbes

Tor Hidden Services And Drug Markets Are Under Attack, But Help Is On The Way

Users of Tor complain Hidden Services are inaccessible or slow as the maintainers of the privacy-focused network warn such sites are indeed...

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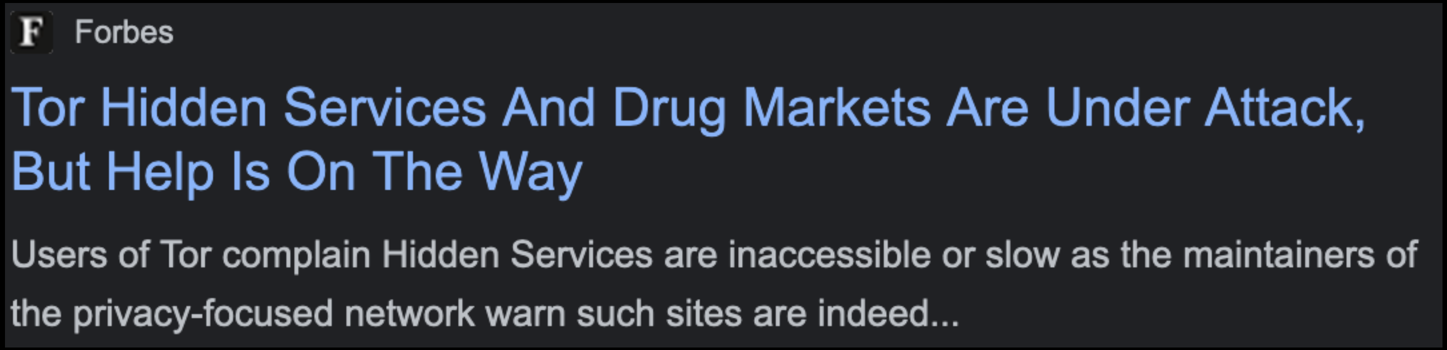

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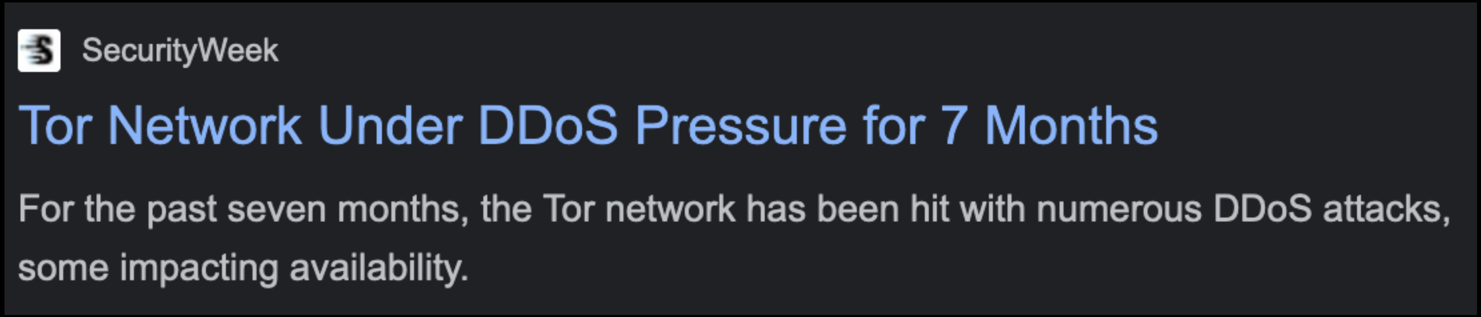
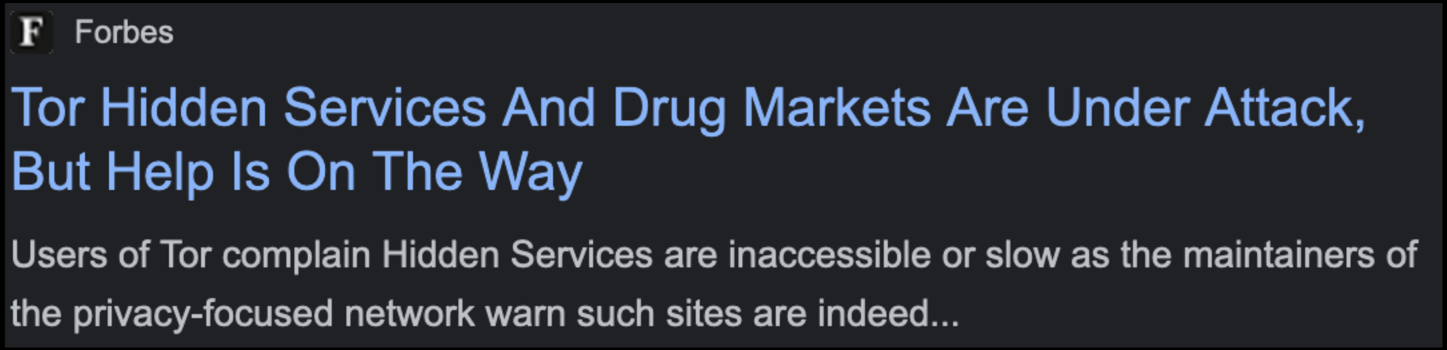


SecurityWeek

Tor Network Under DDoS Pressure for 7 Months

For the past seven months, the Tor network has been hit with numerous DDoS attacks, some impacting availability.

Tor in the News



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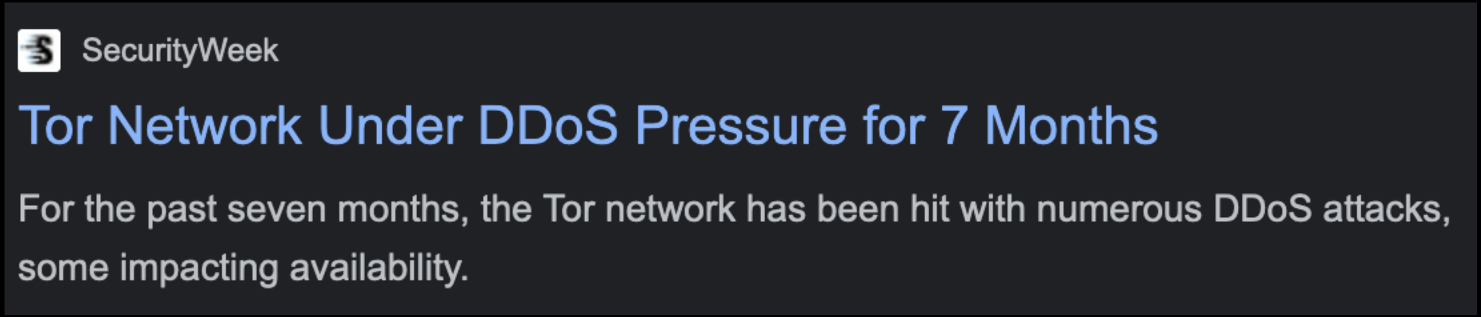

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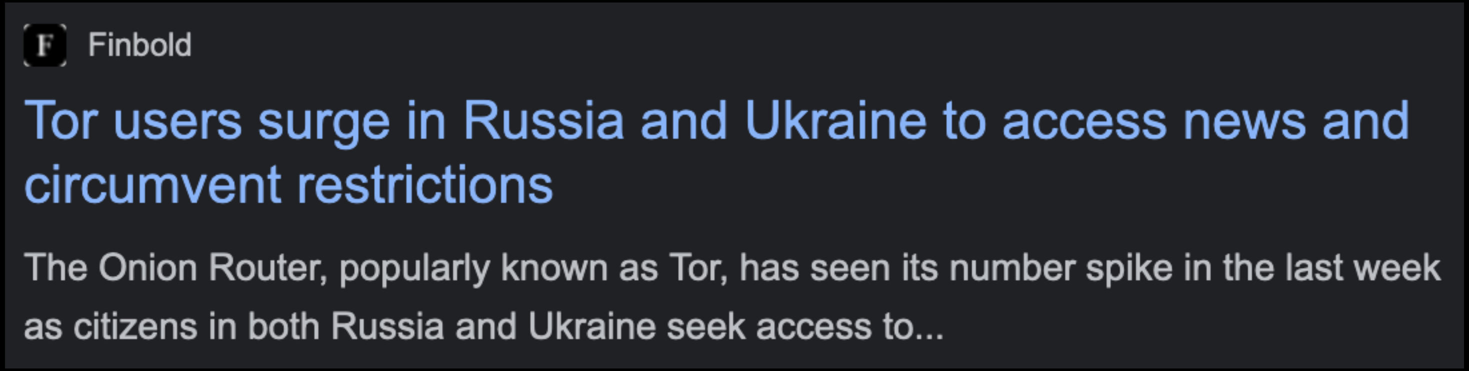

Finbold

Tor users surge in Russia and Ukraine to access news and circumvent restrictions

The Onion Router, popularly known as Tor, has seen its number spike in the last week as citizens in both Russia and Ukraine seek access to...

The Onion Routing

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📍 7k+ Relays

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2M/Day

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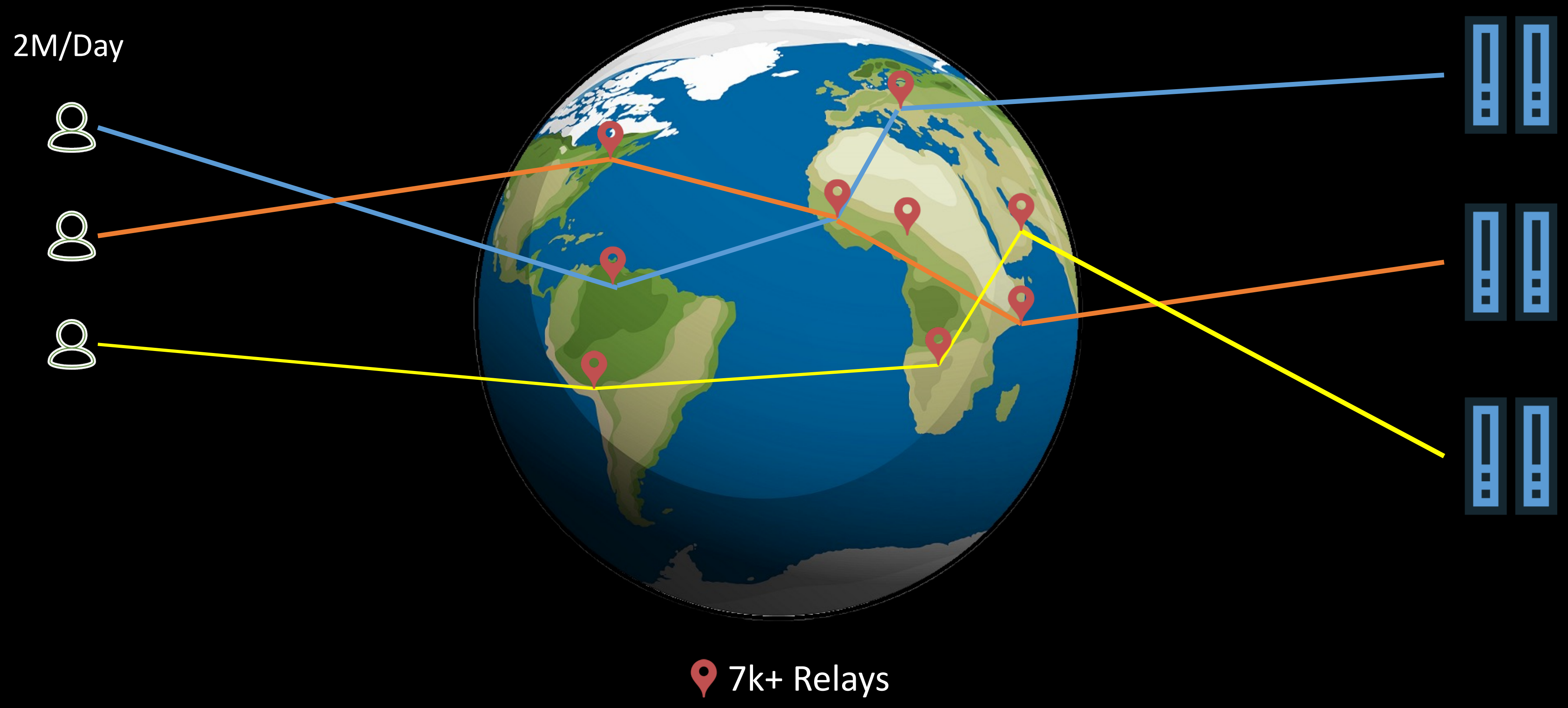

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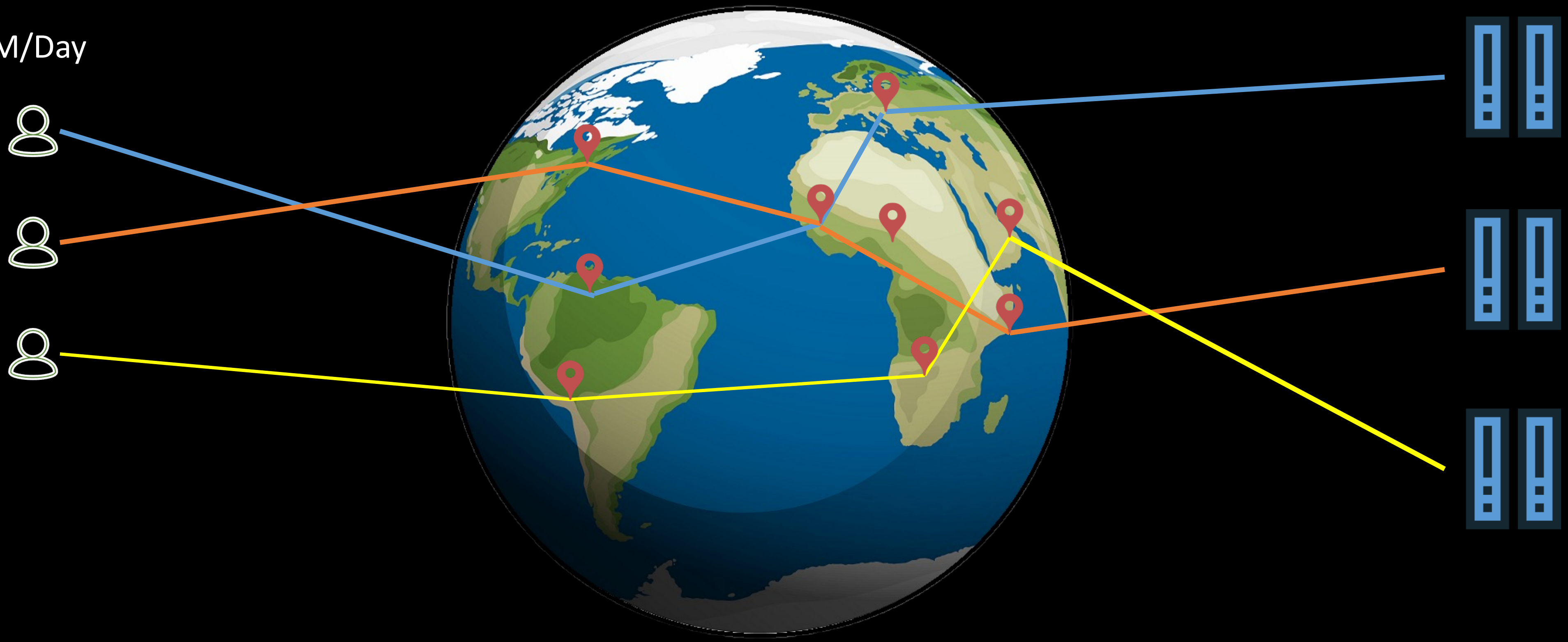
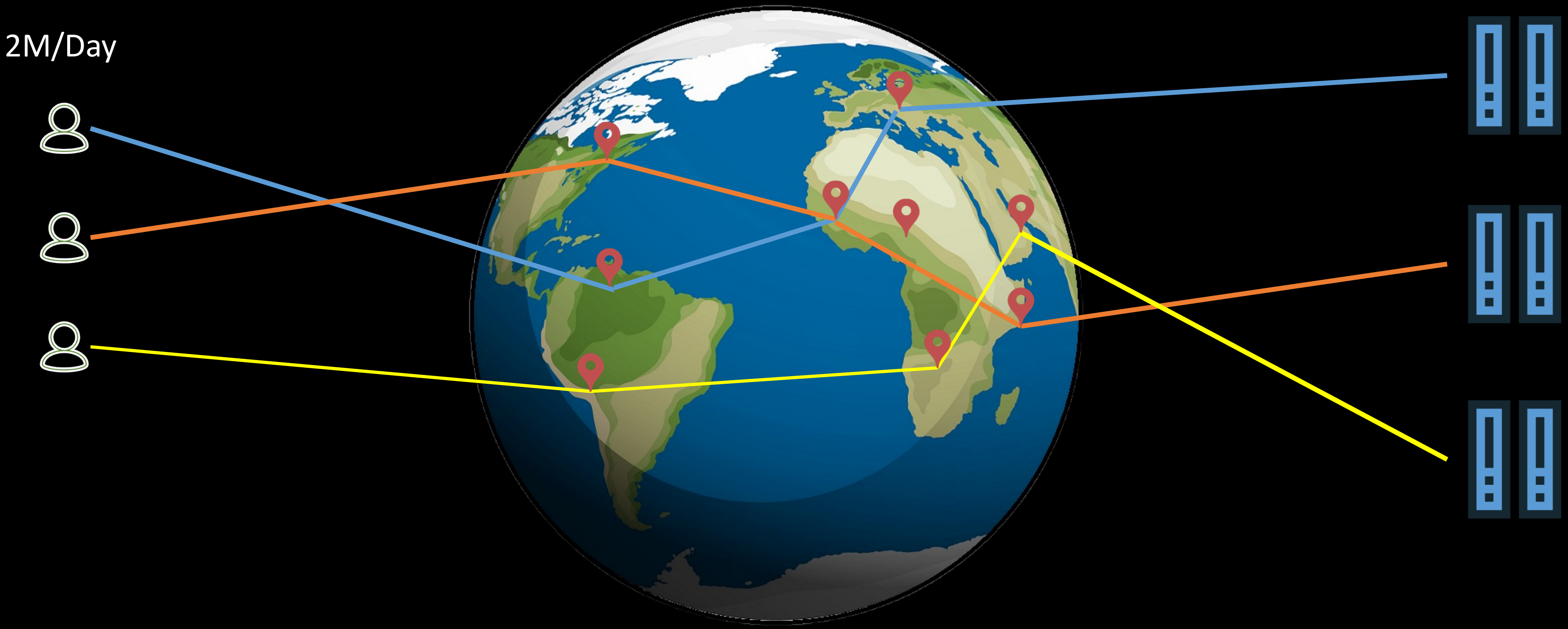


📍 7k+ Relays

300 Gbit/s user traffic

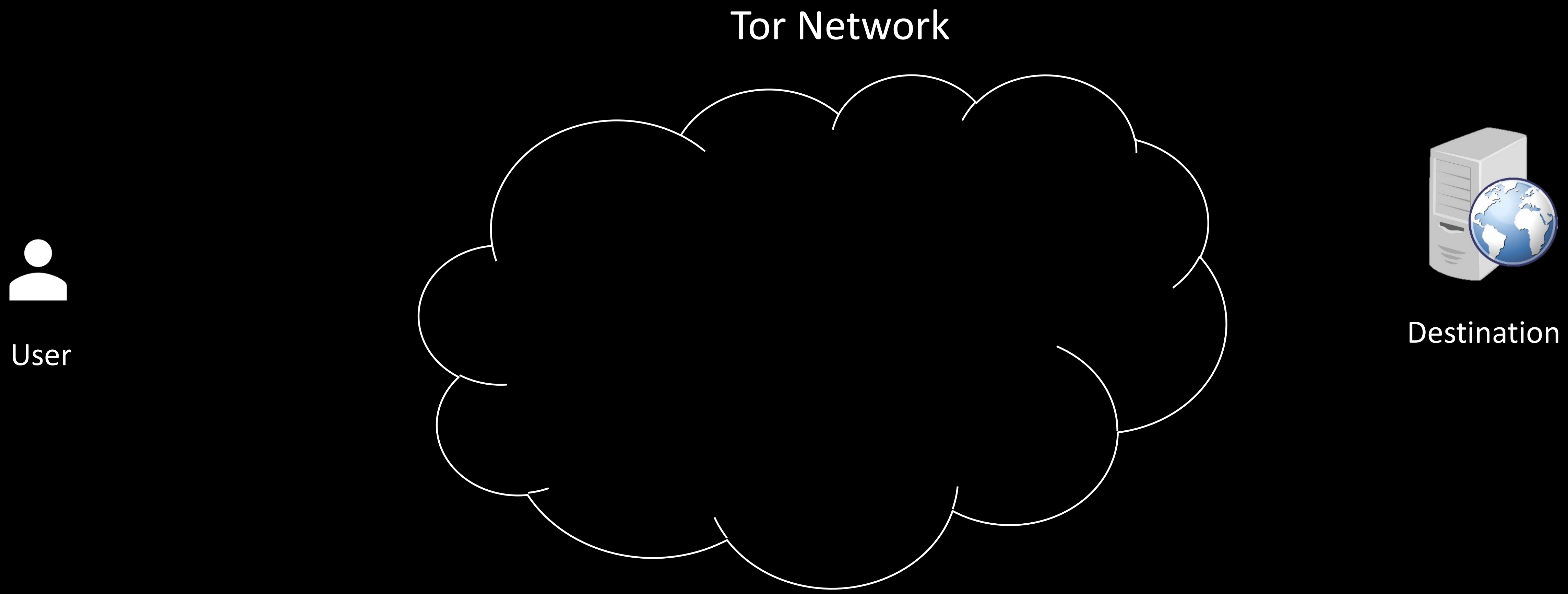
The Onion Routing



📍 7k+ Relays

300 Gbit/s user traffic
750 Gbit/s advertised

Tor Network

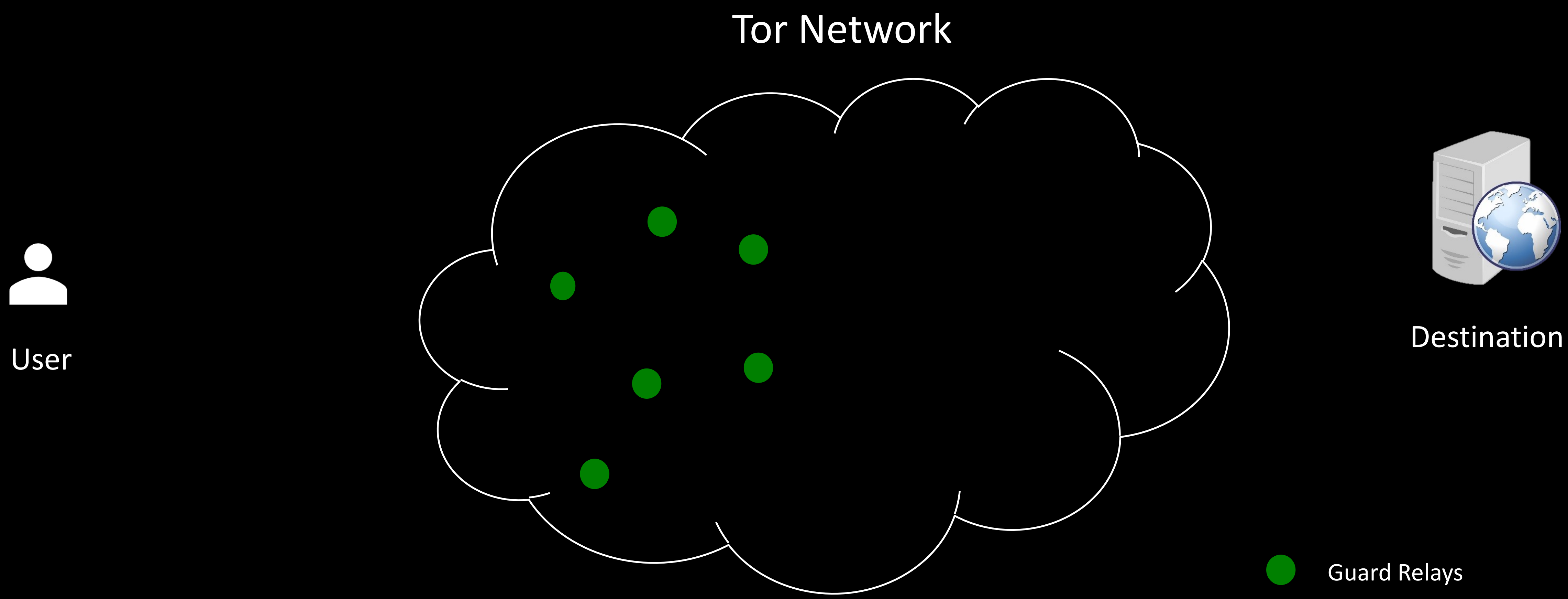


Tor Network

User

Destination

Tor Network



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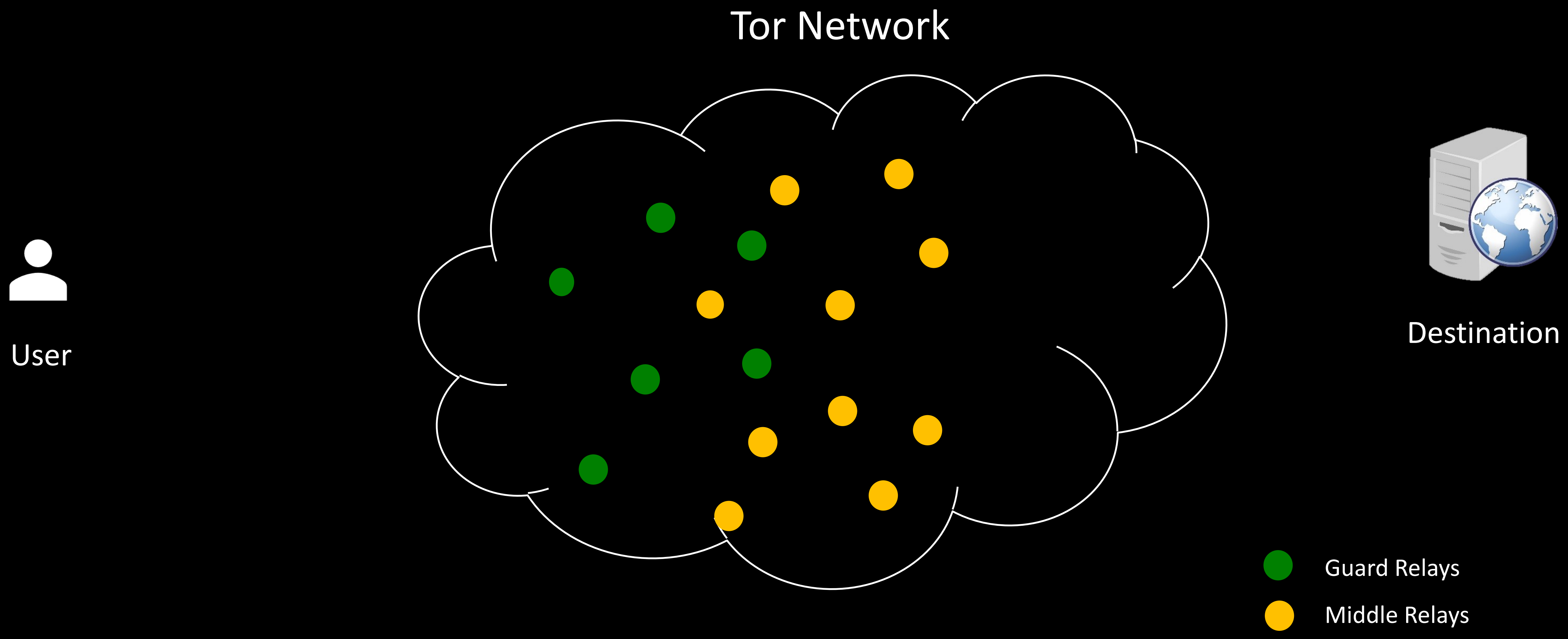


Tor Network

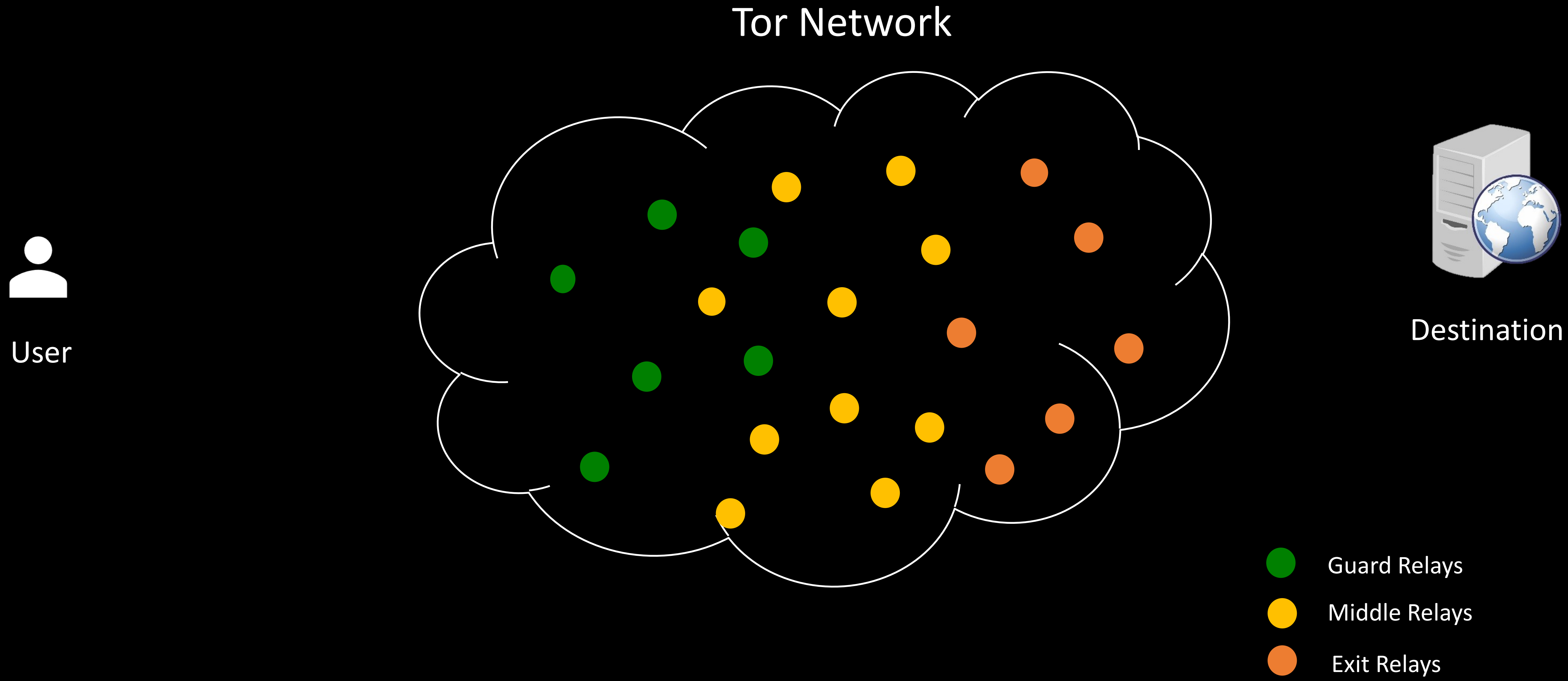
User

Destination

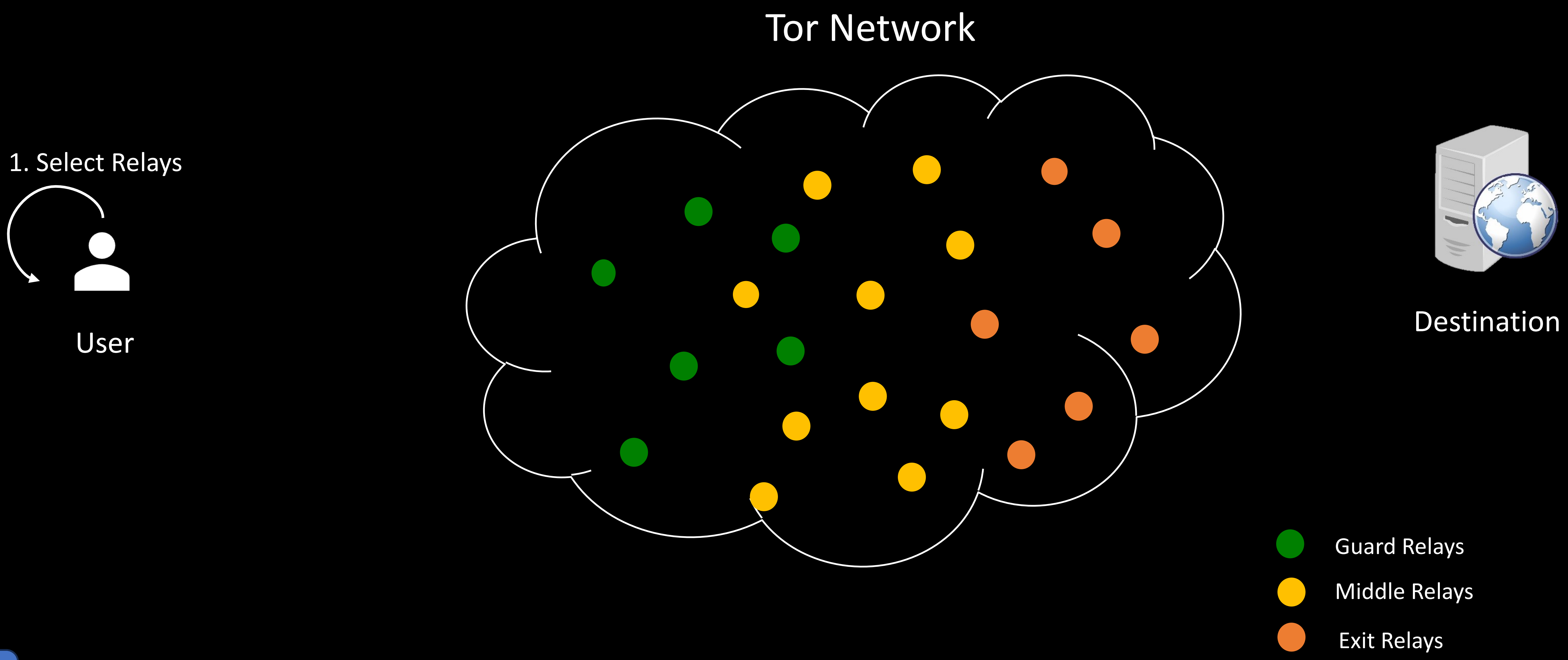
🟢 Guard Relays

🟡 Middle Relays

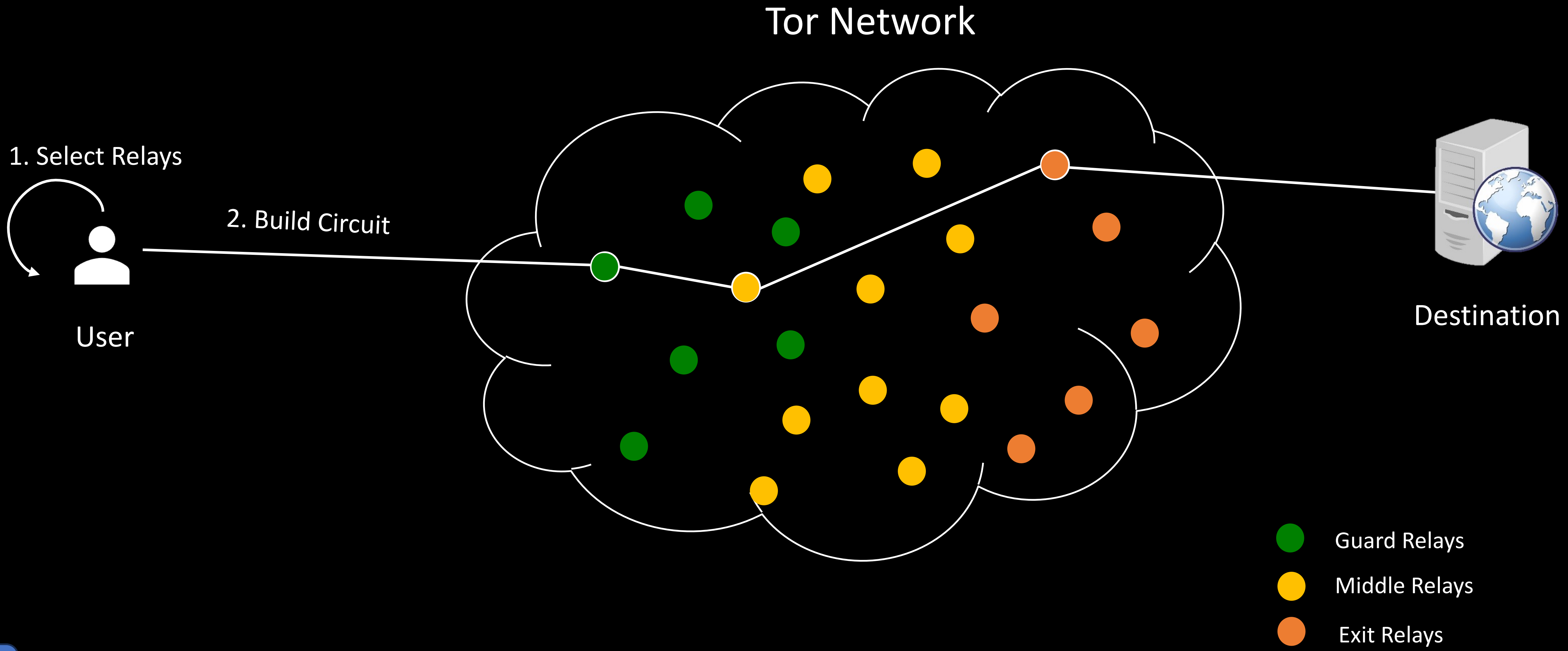
Tor Network


Tor Network
User
Destination
Guard Relays
Middle Relays
Exit Relays

Tor Network


Tor Network
1. Select Relays
User
Destination
Guard Relays
Middle Relays
Exit Relays

Tor Network


Tor Network
1. Select Relays
2. Build Circuit
User
Destination
● Guard Relays
● Middle Relays
● Exit Relays

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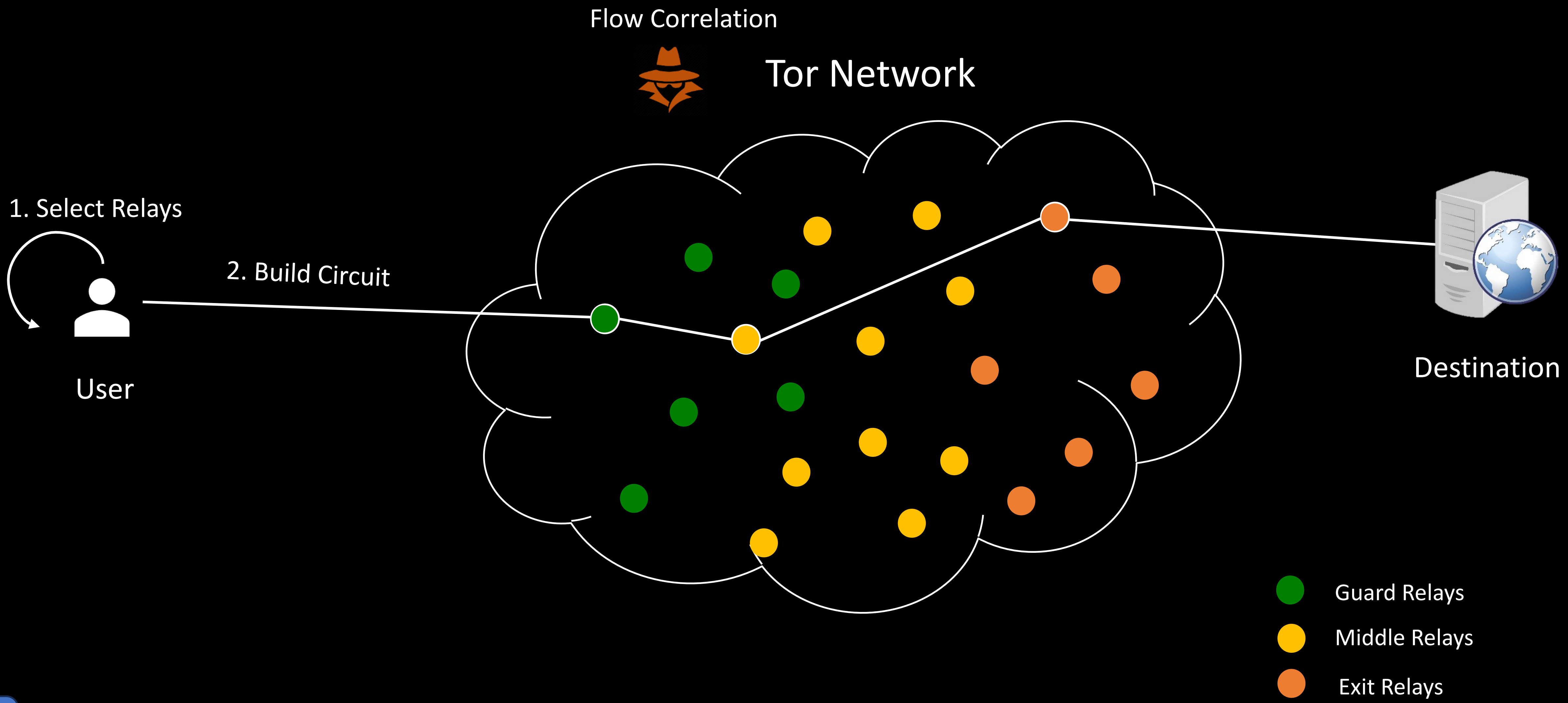
Flow Correlation
Tor Network
1. Select Relays
2. Build Circuit
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Middle Relays
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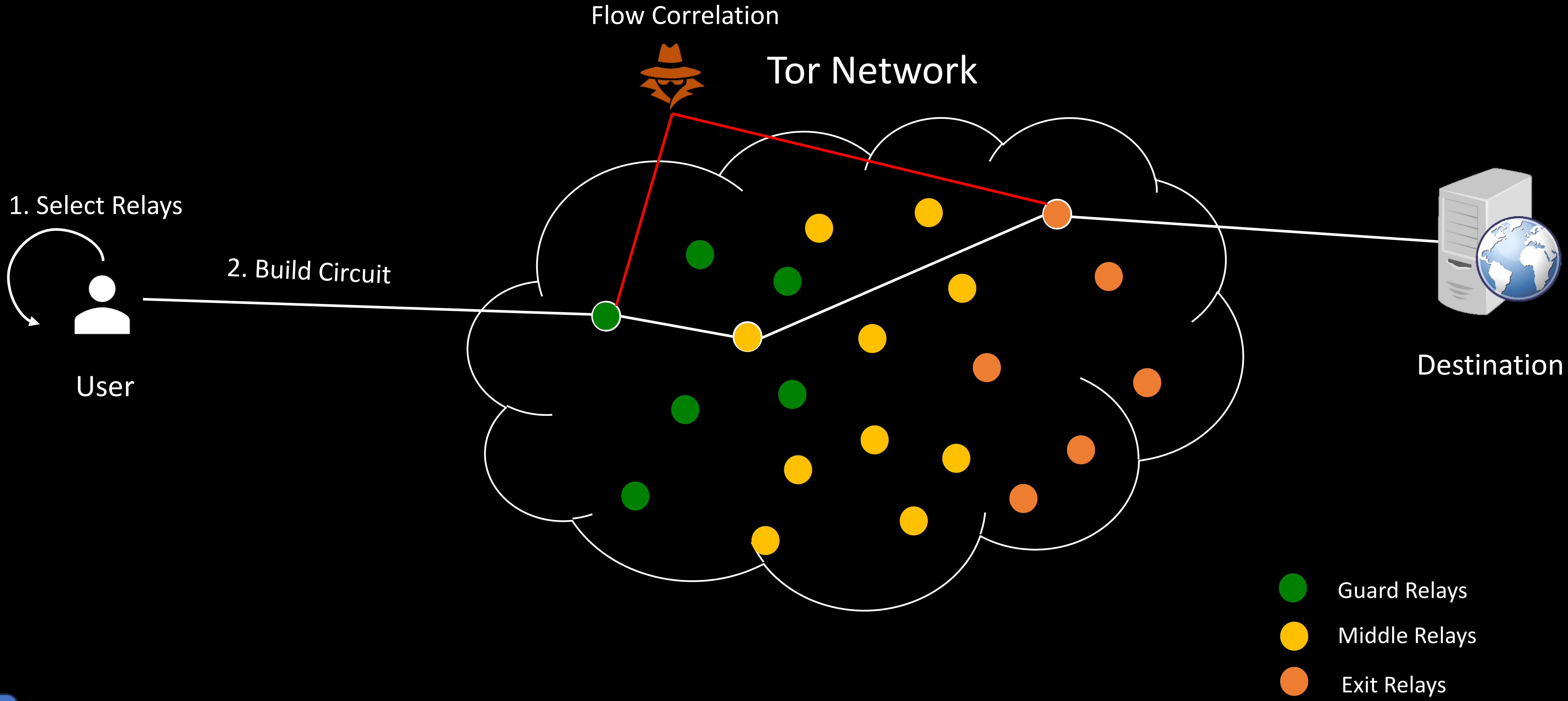
Tor Network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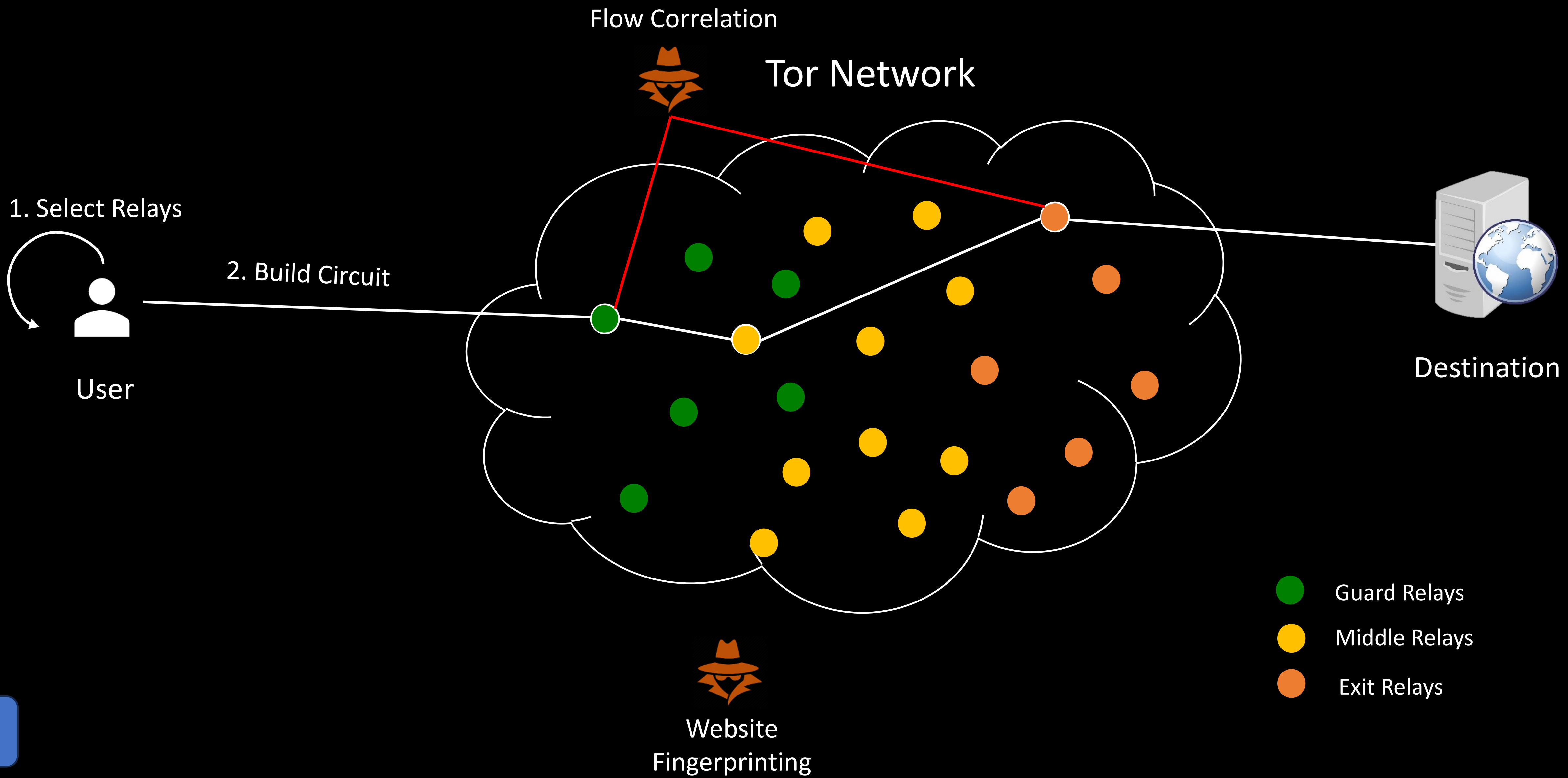
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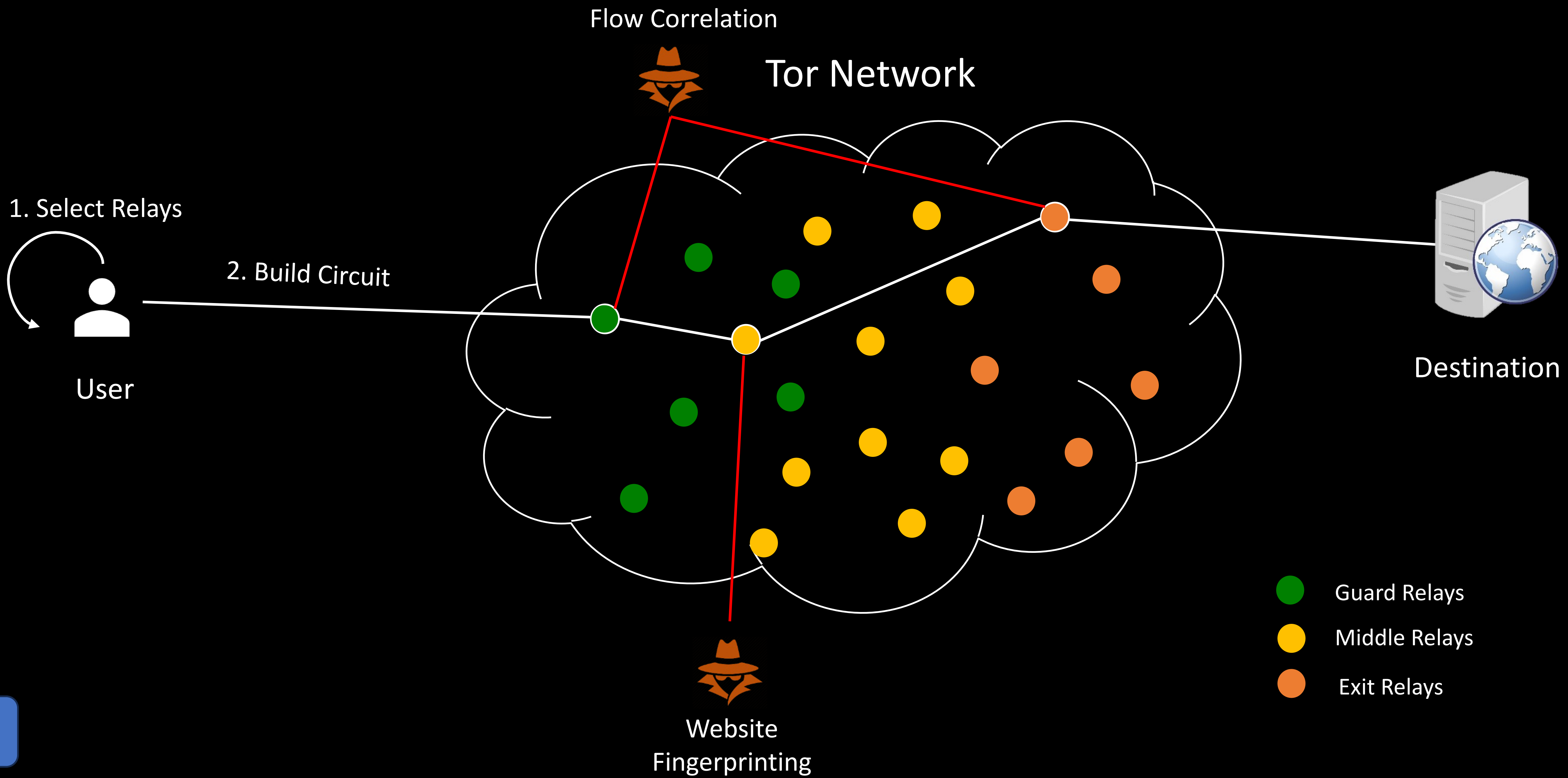
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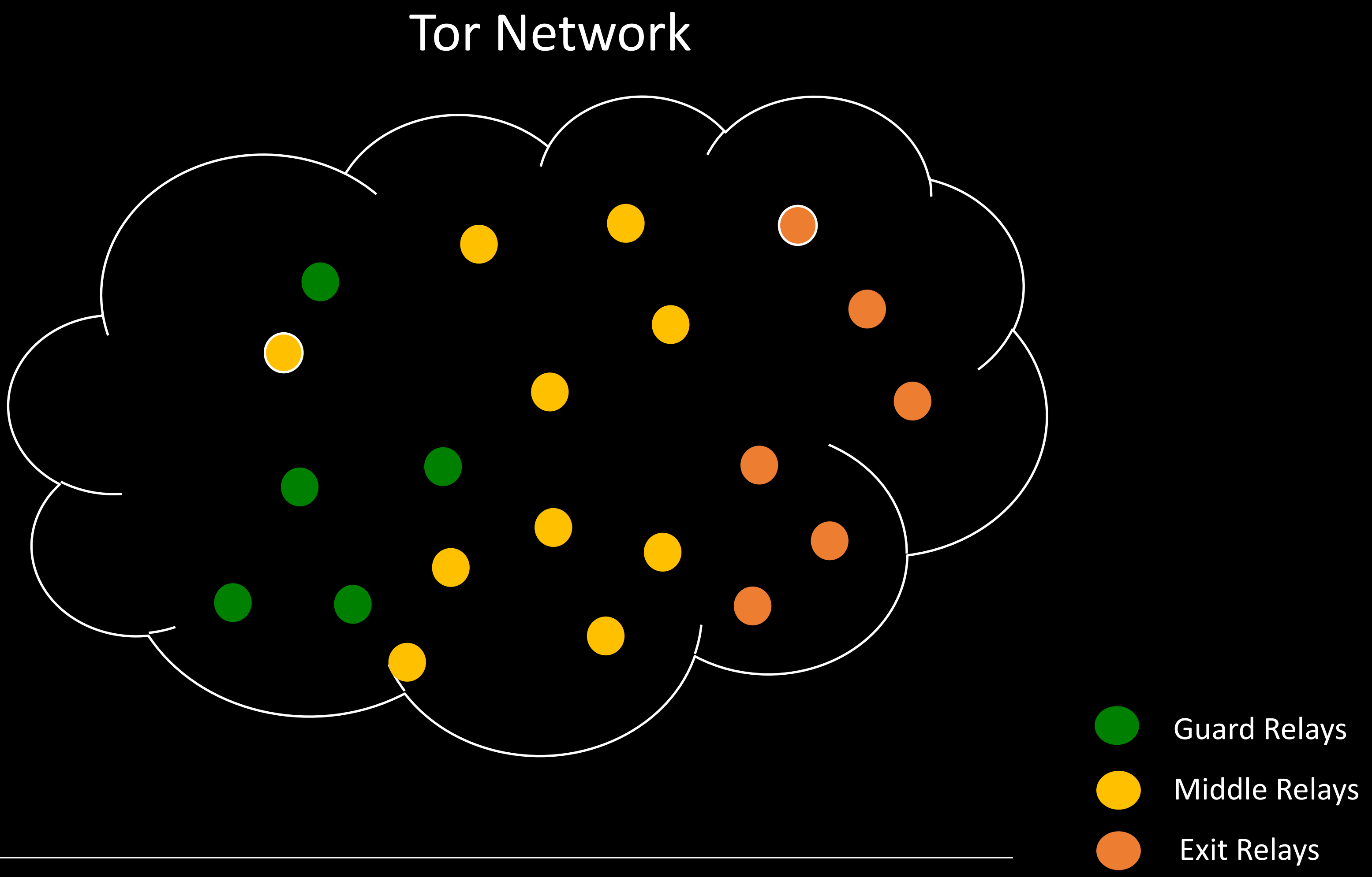

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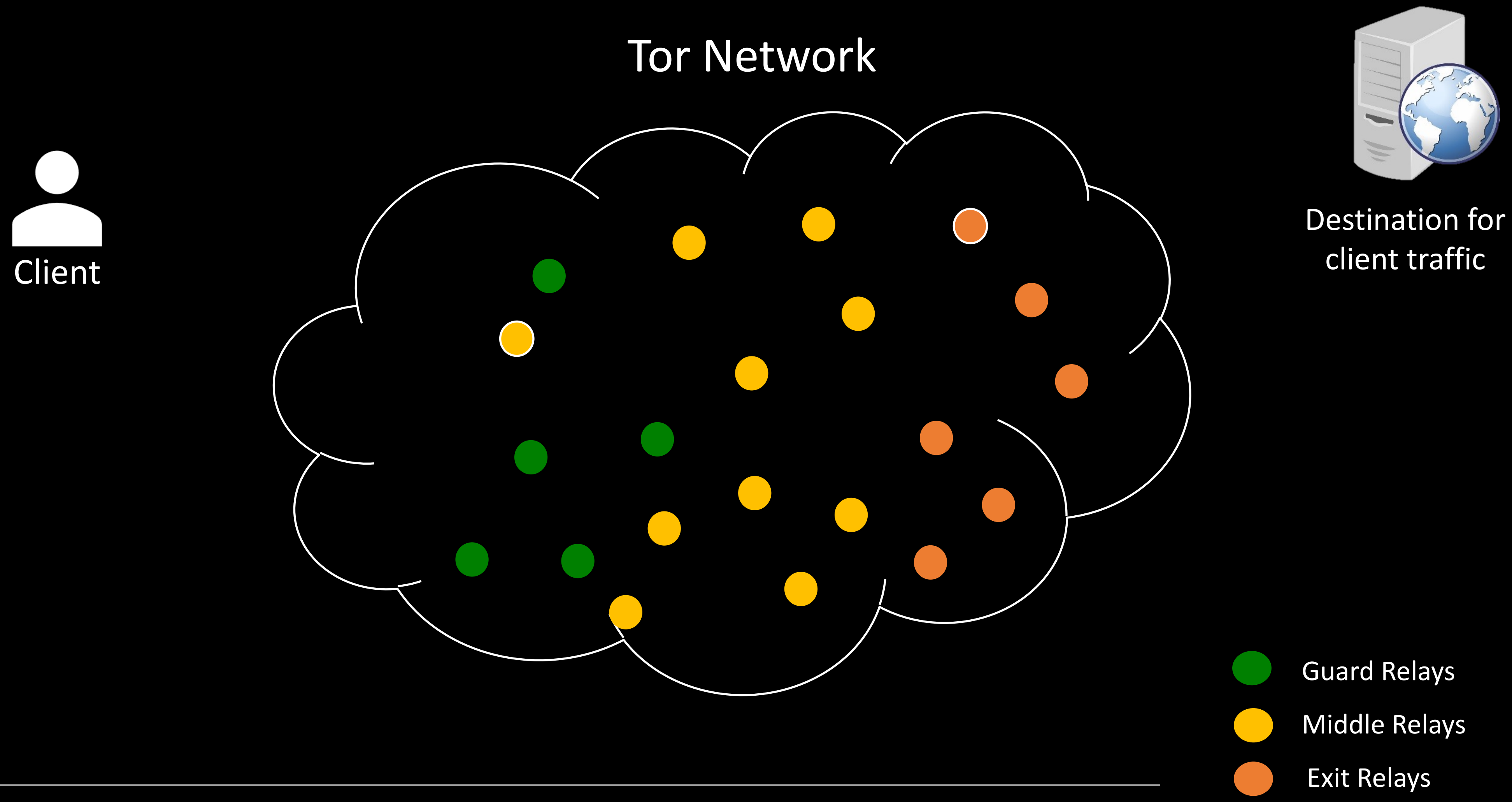

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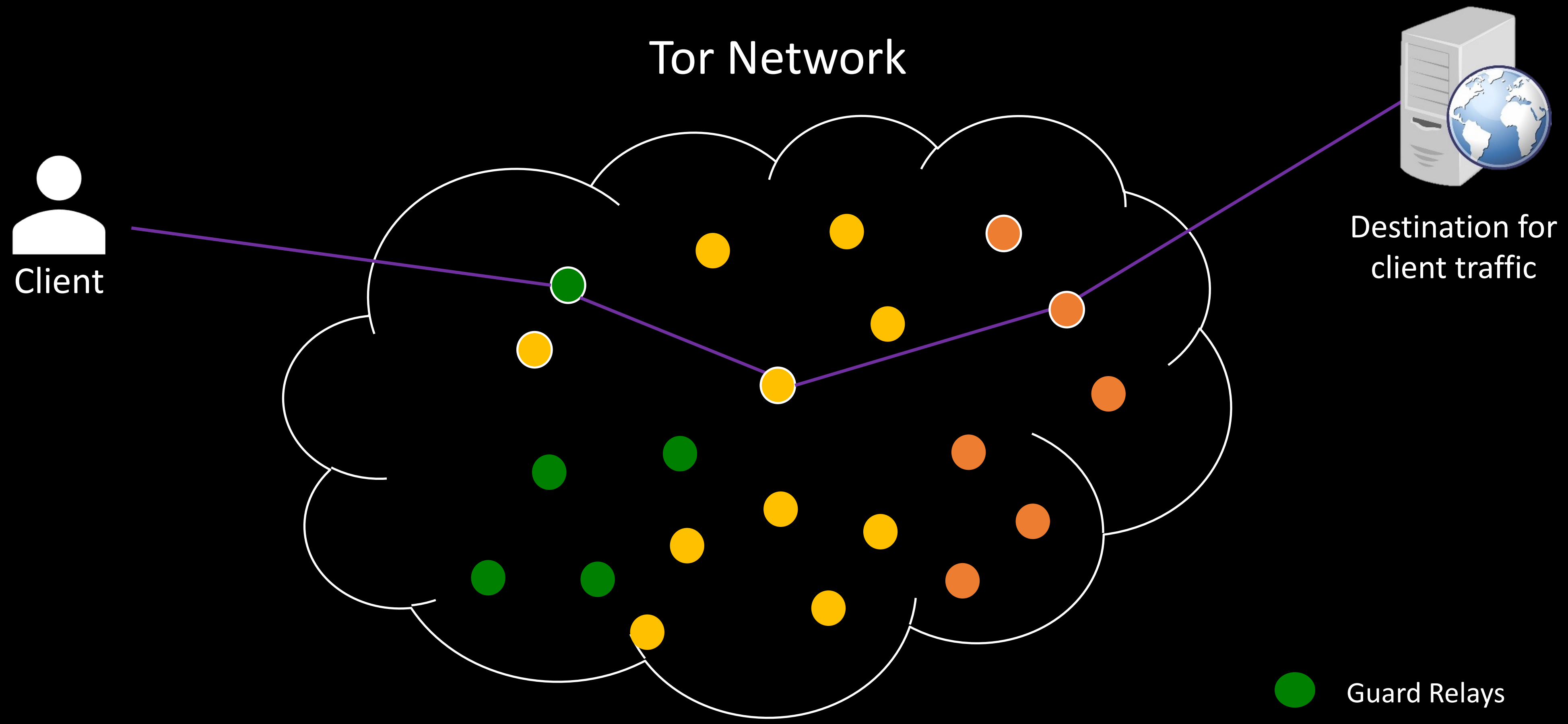

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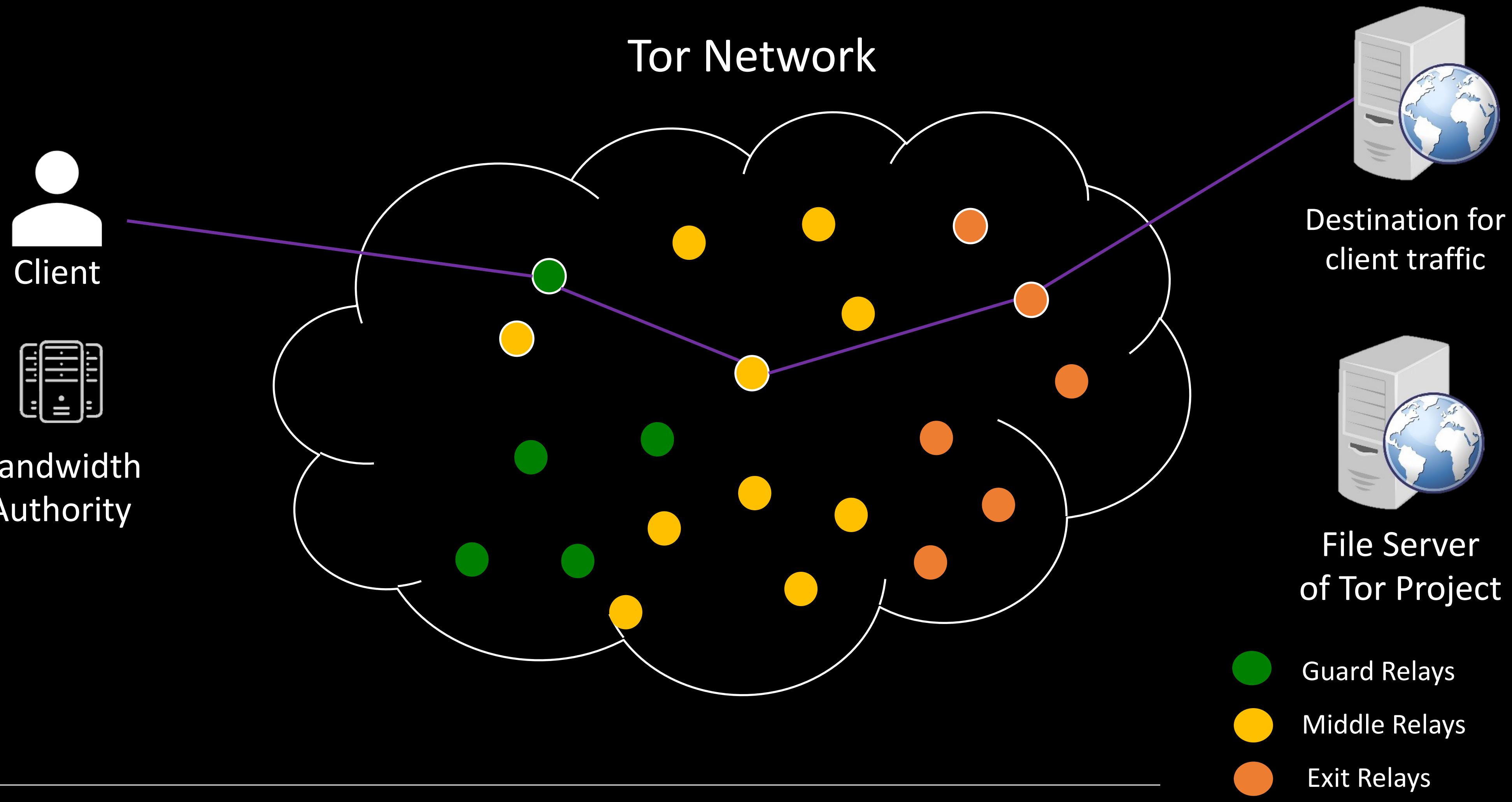

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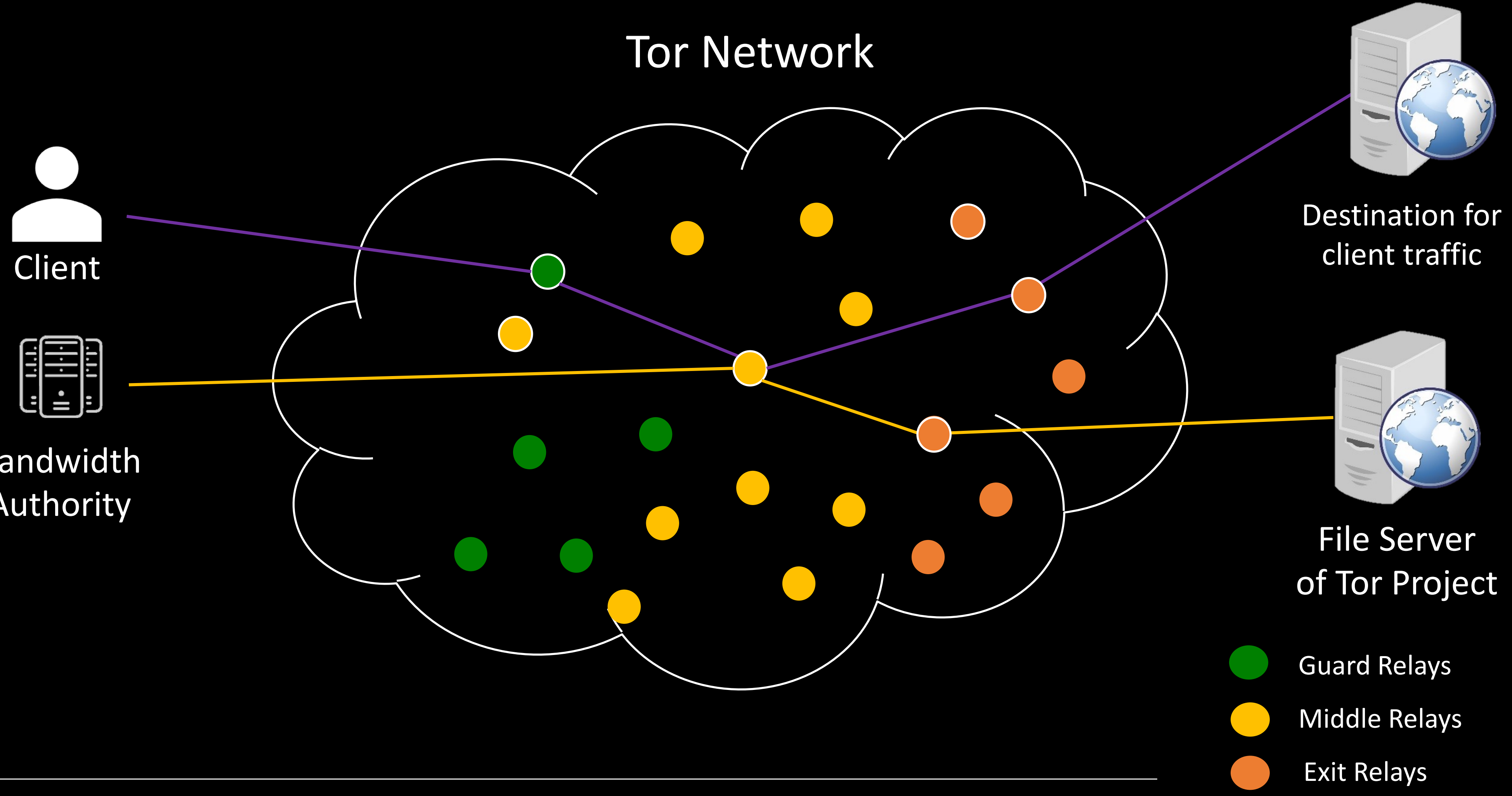

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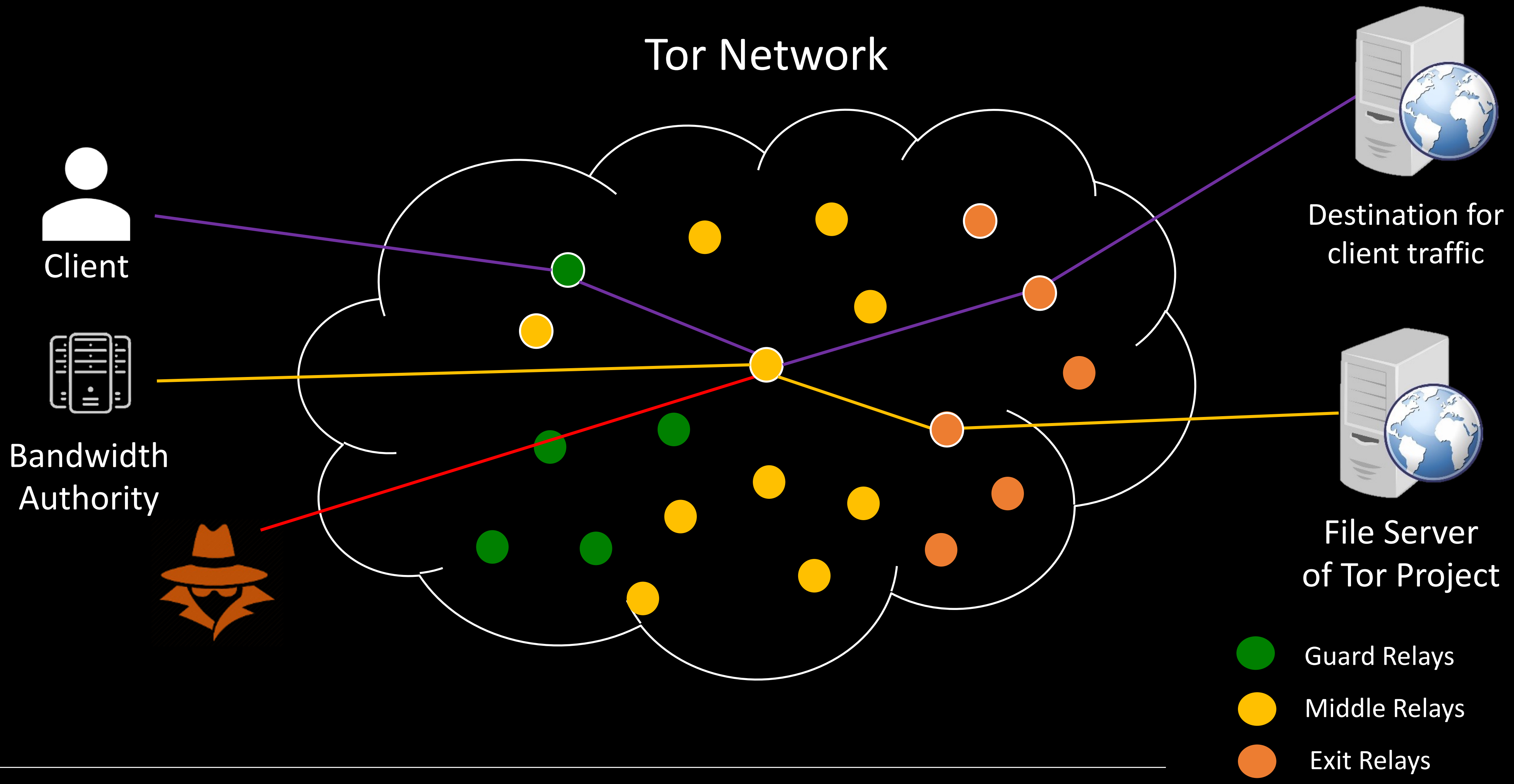

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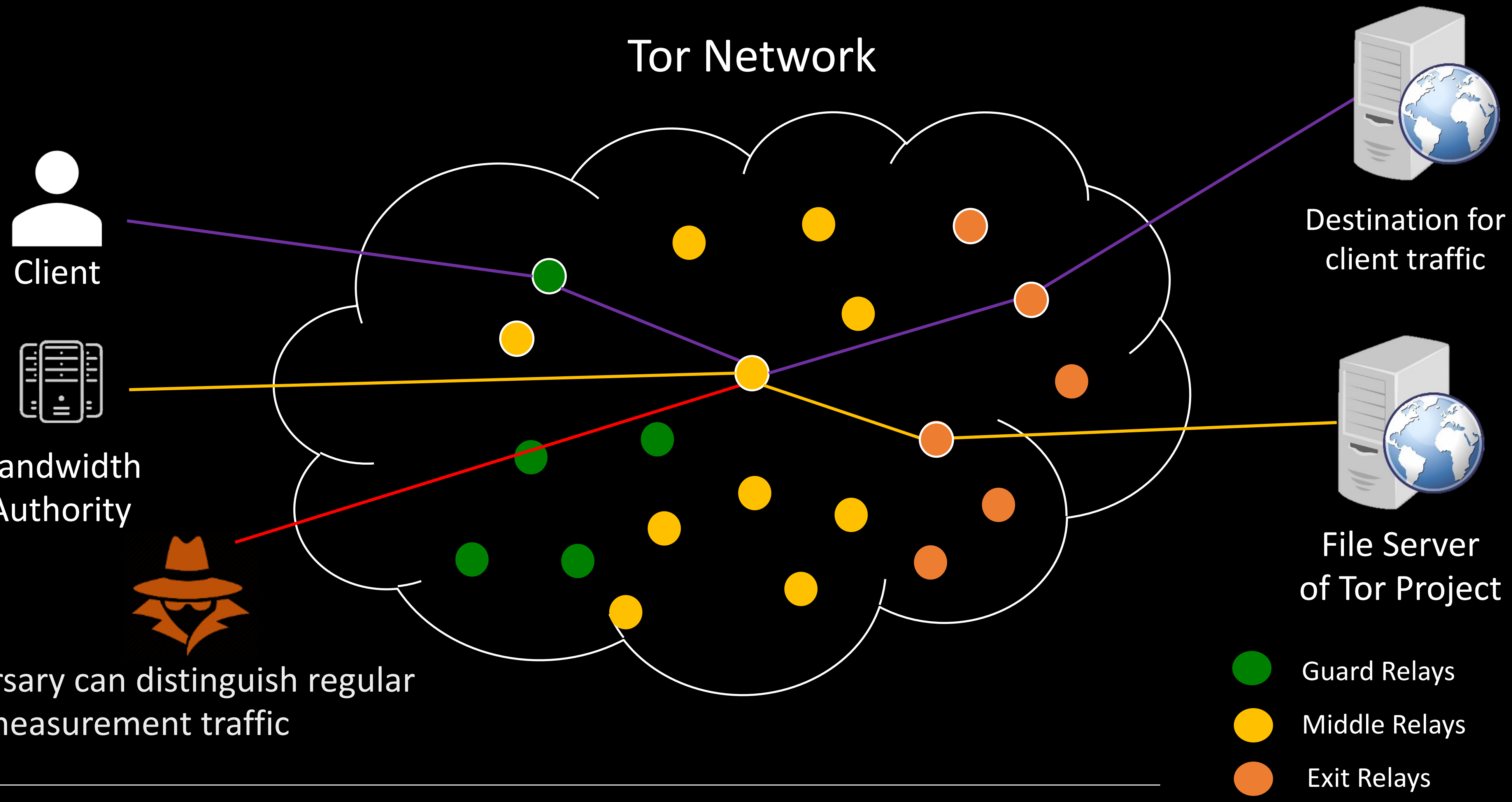

Adversary can distinguish regular and measurement traffic

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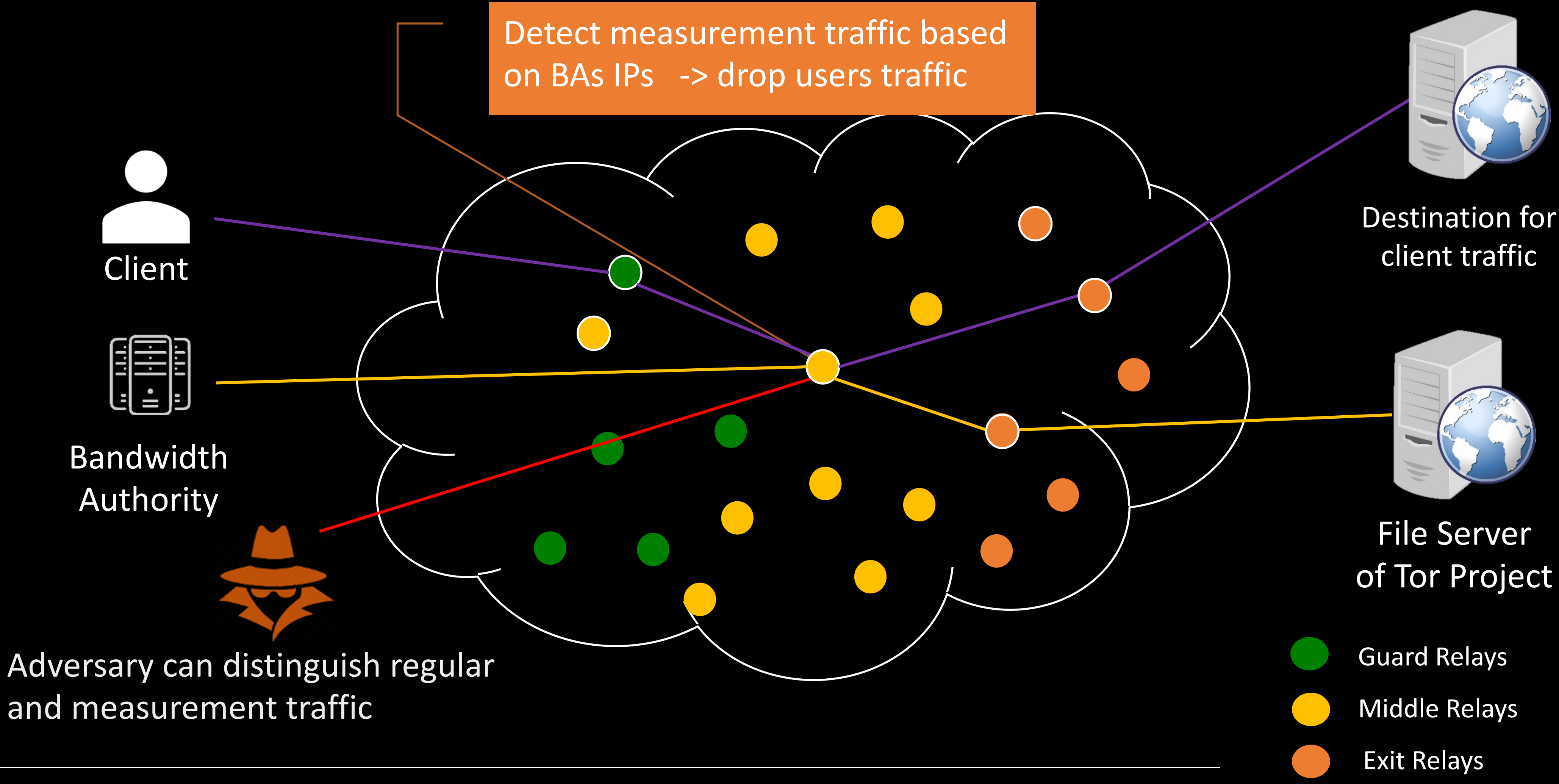
Detect measurement traffic based on BAs IPs -> drop users traffic
Client
Bandwidth Authority
Destination for client traffic
File Server of Tor Project
Guard Relays
Middle Relays
Exit Relays

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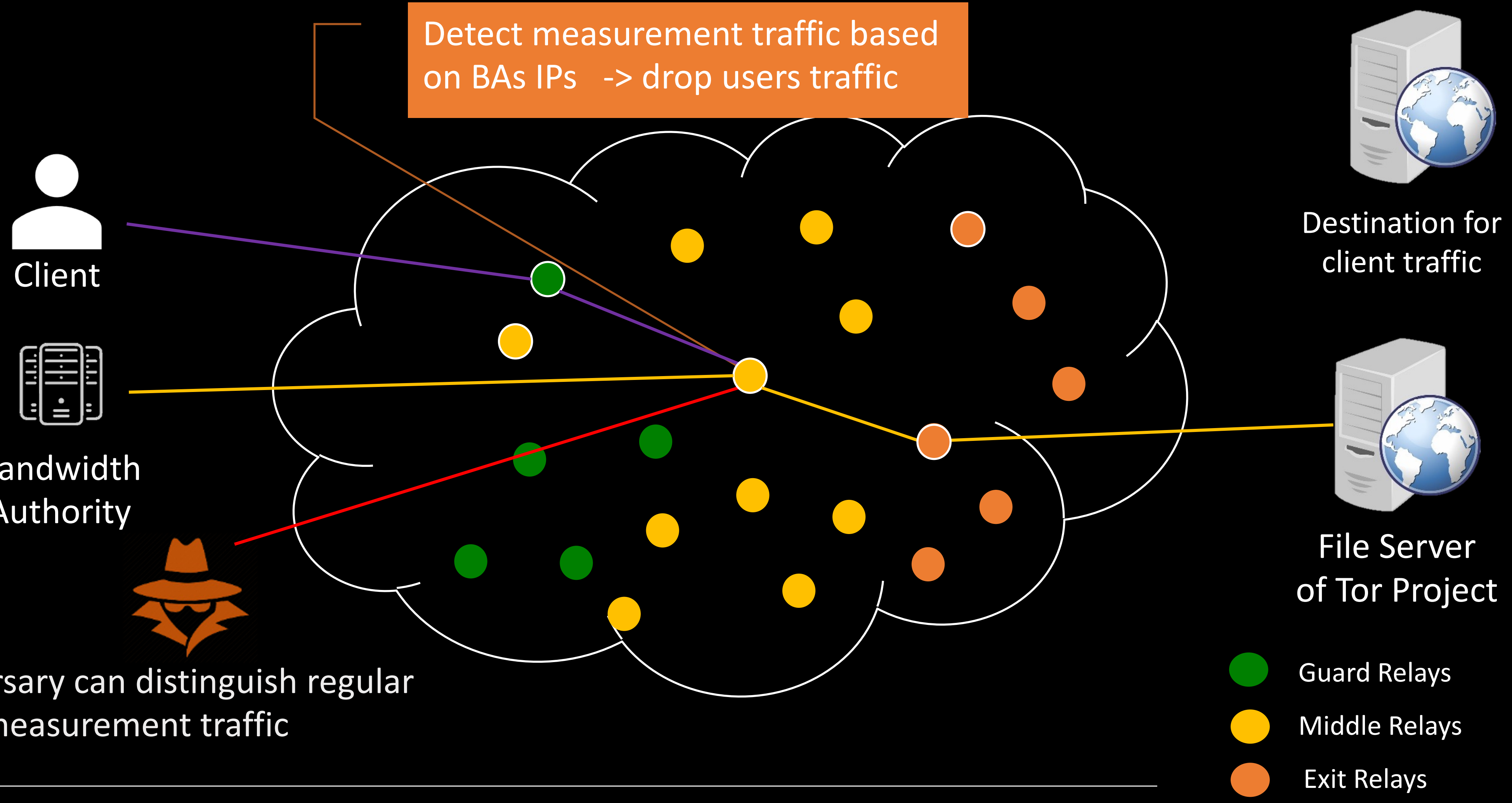

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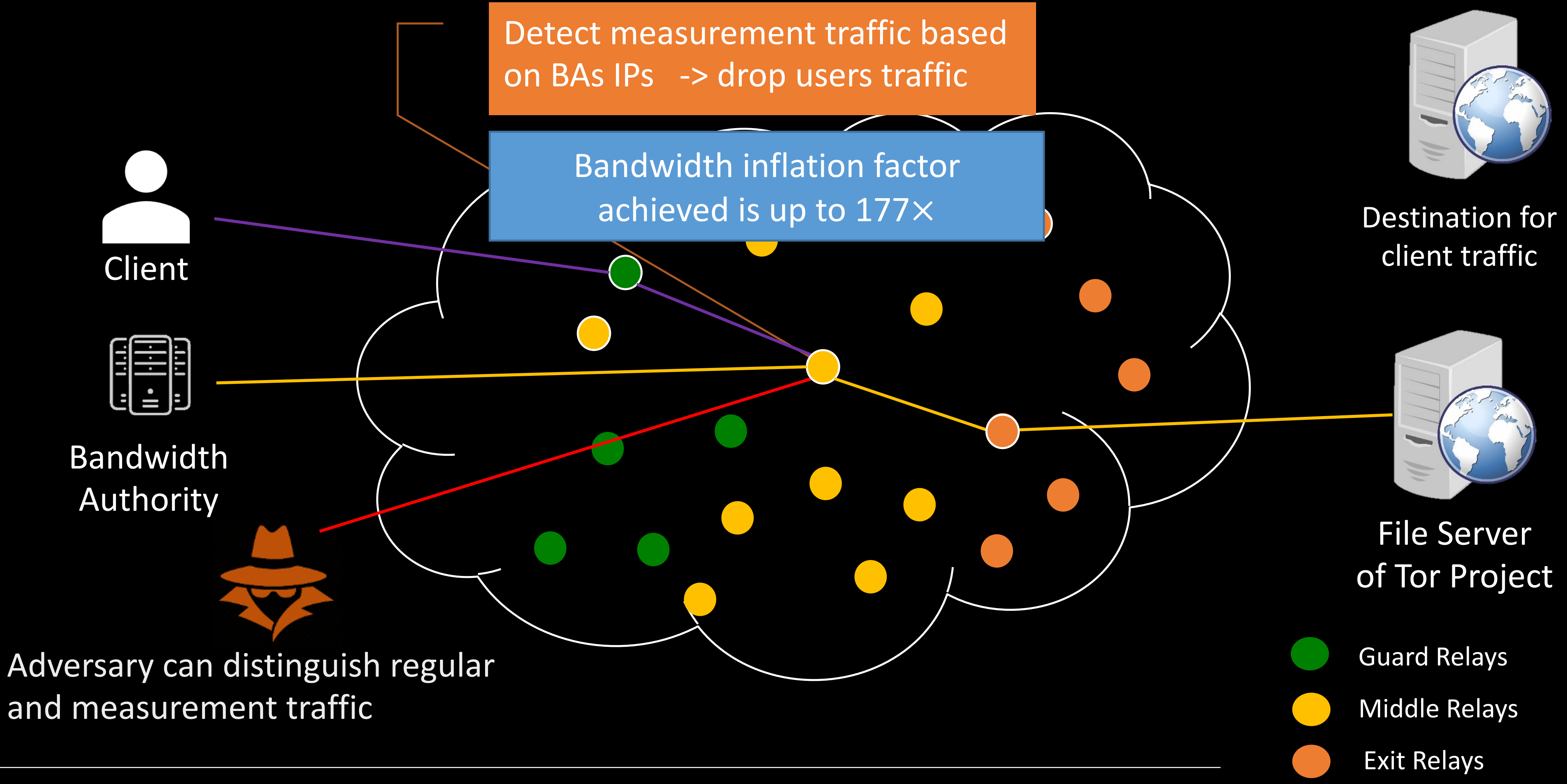

Detect measurement traffic based on BAs IPs -> drop users traffic

Bandwidth inflation factor achieved is up to 177×

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- Two attack variants:
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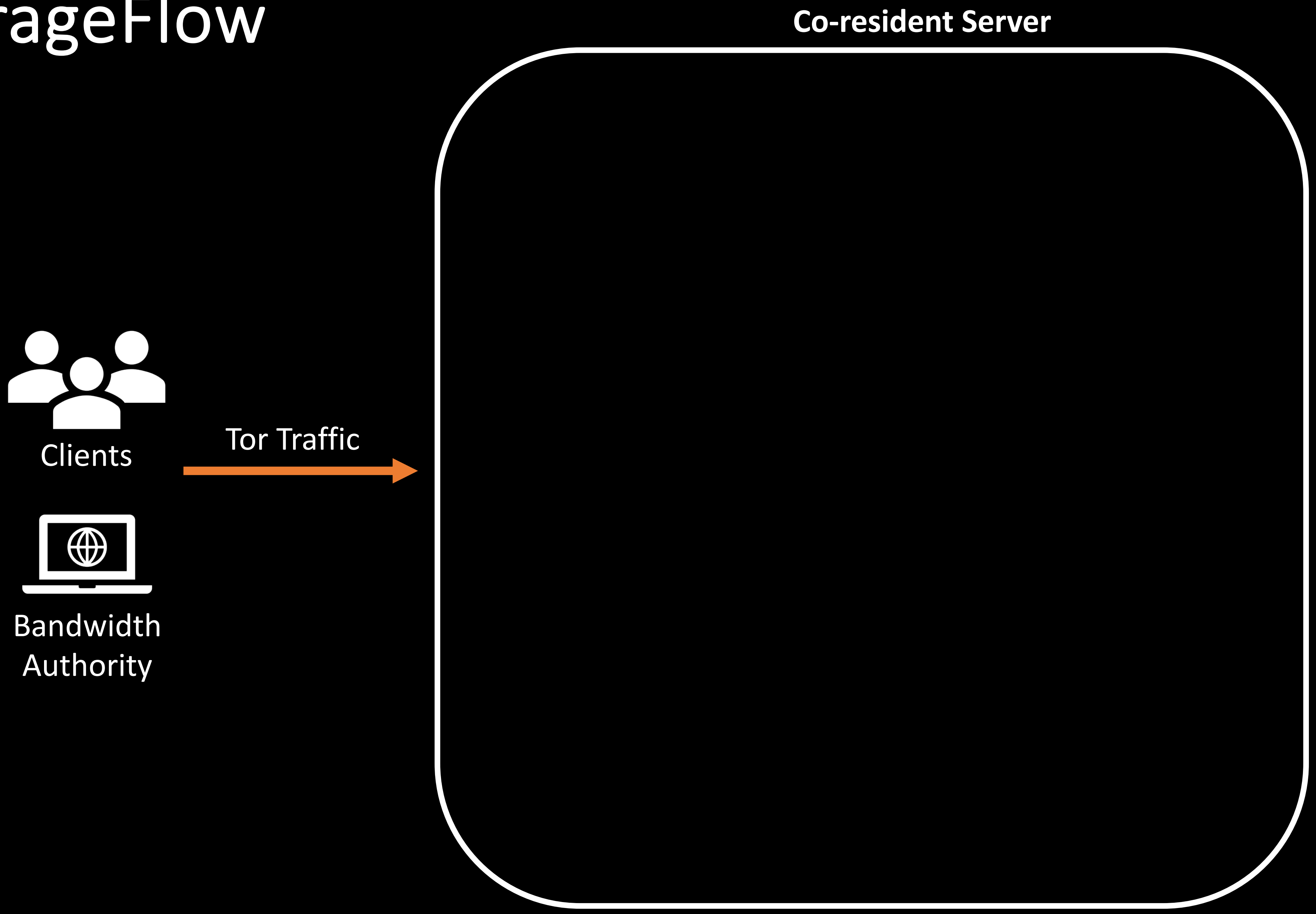
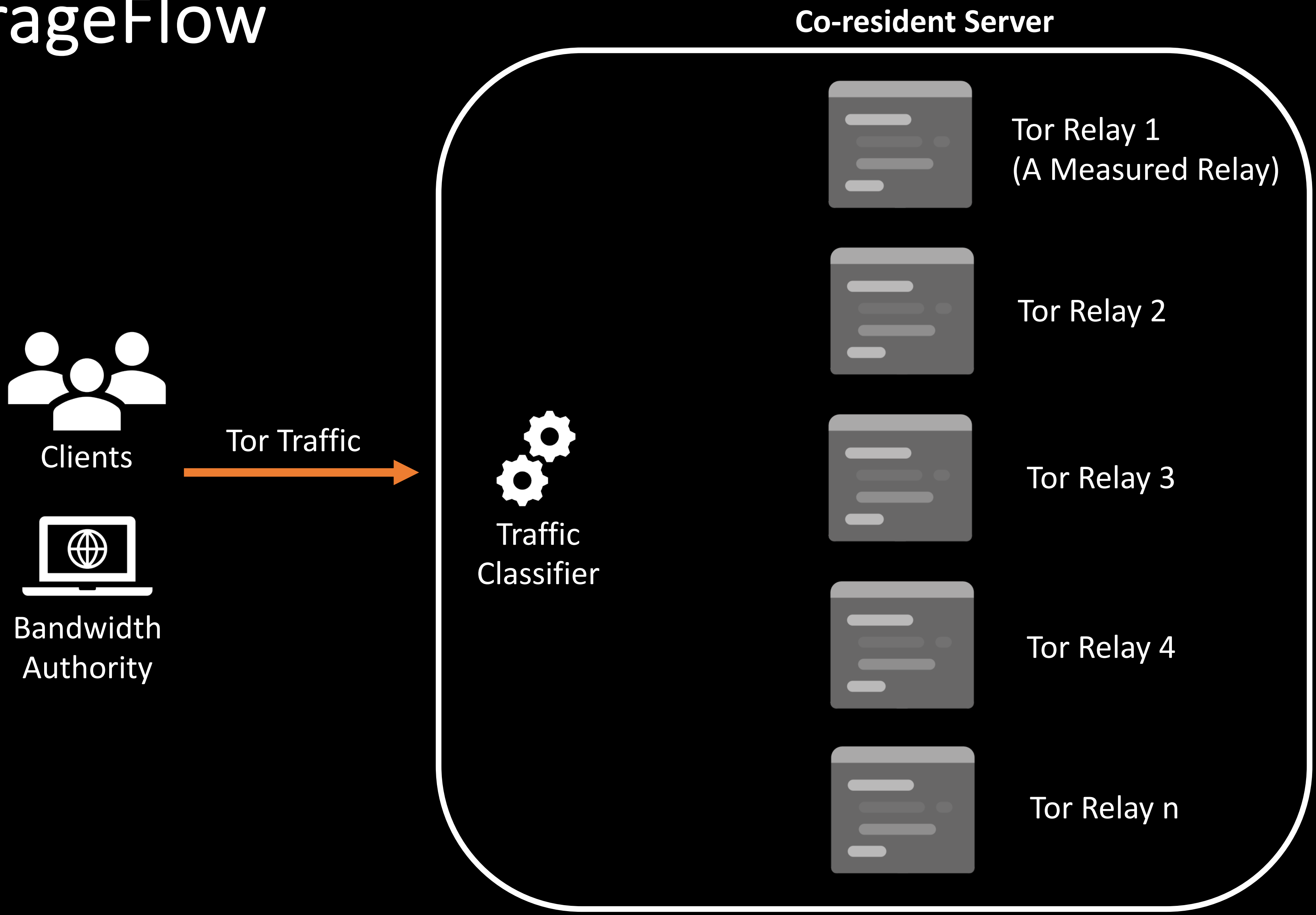
  - D-MirageFlow (Use one powerful and many weak servers)

C-MirageFlow



C-MirageFlow



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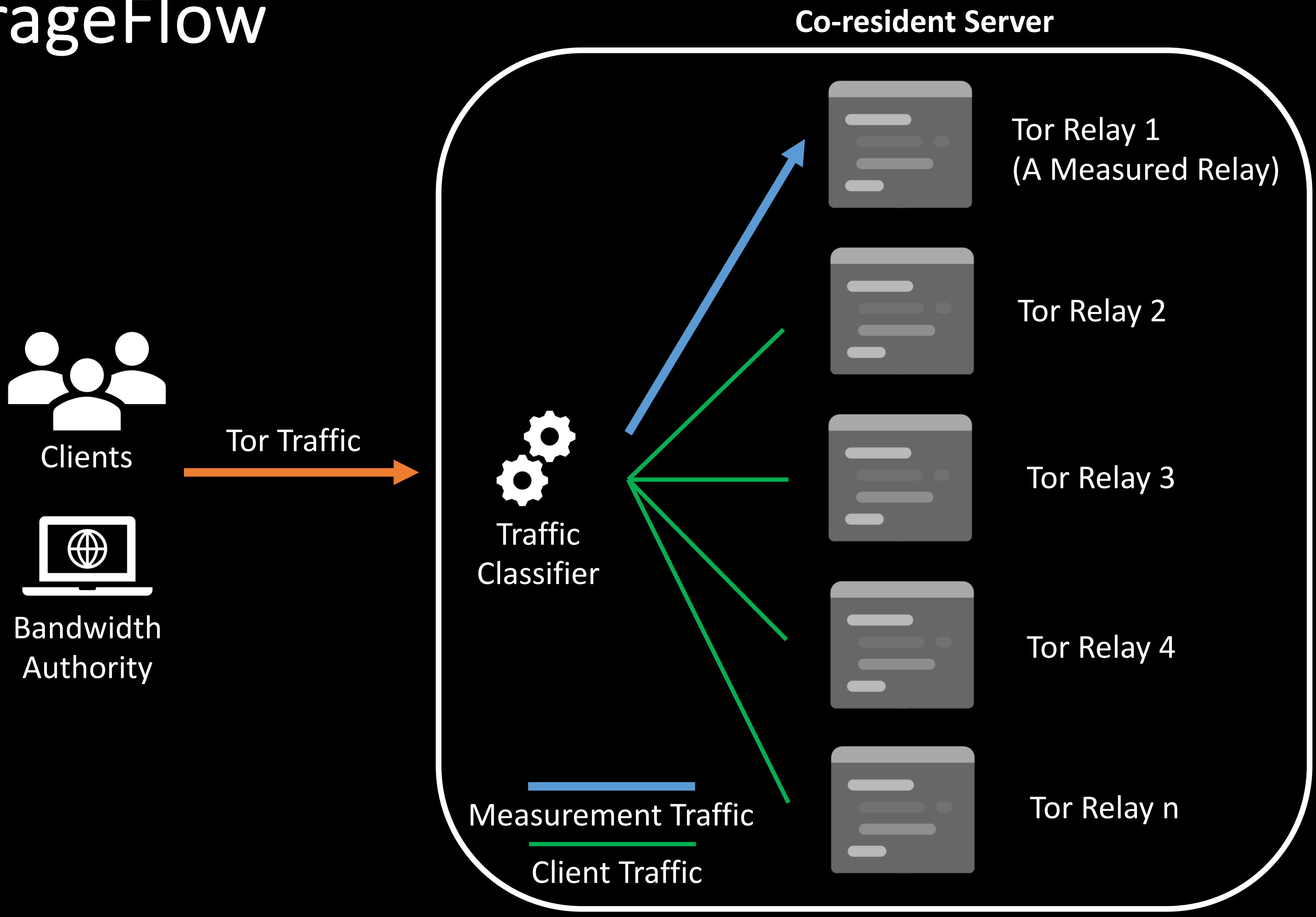

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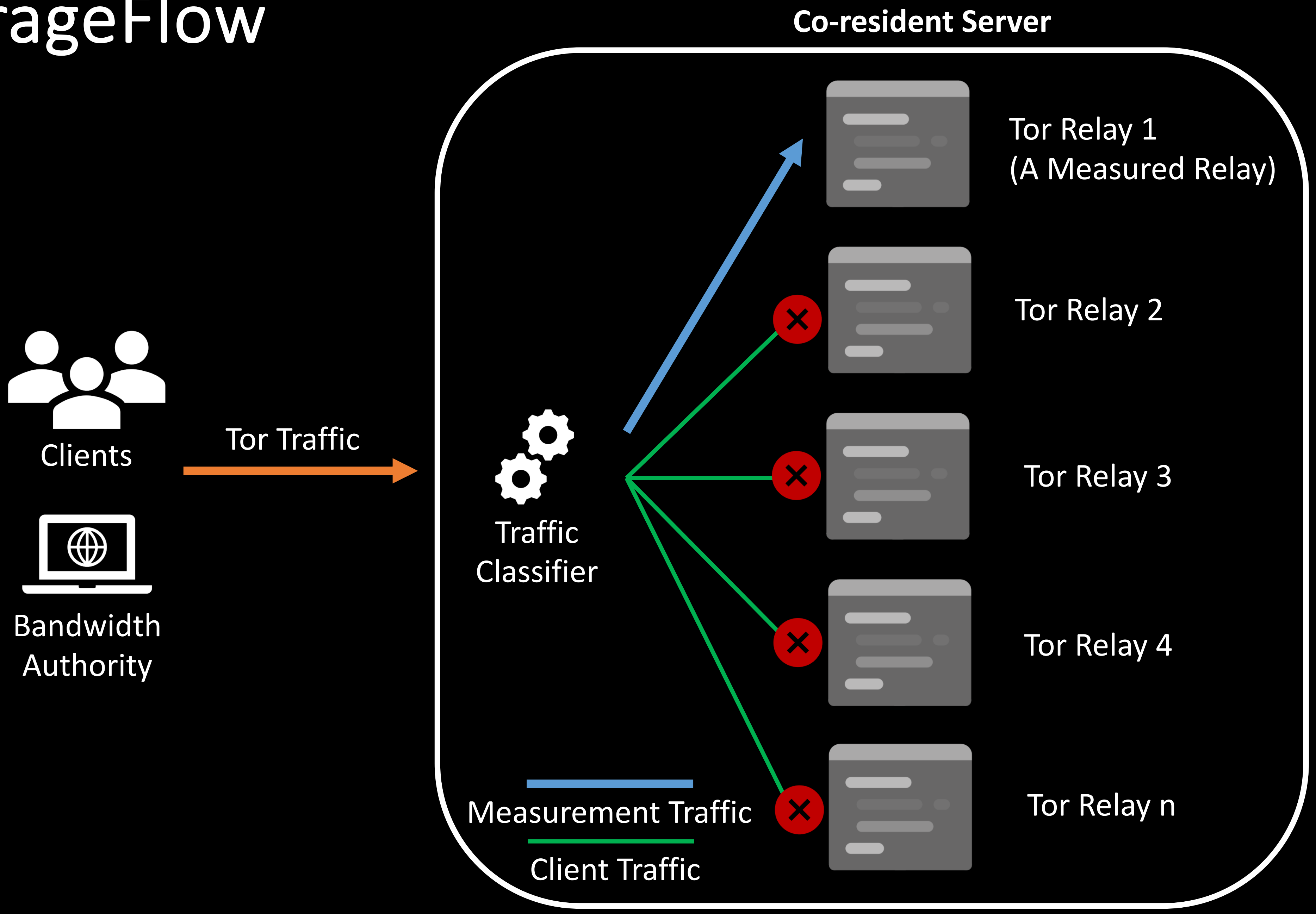

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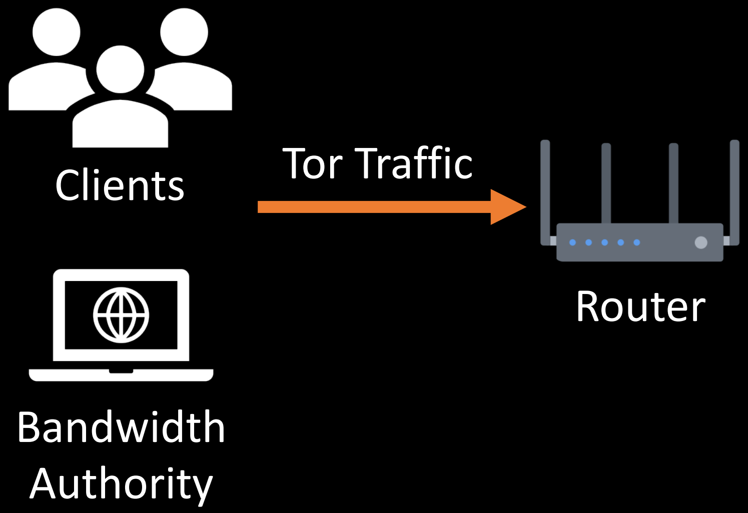

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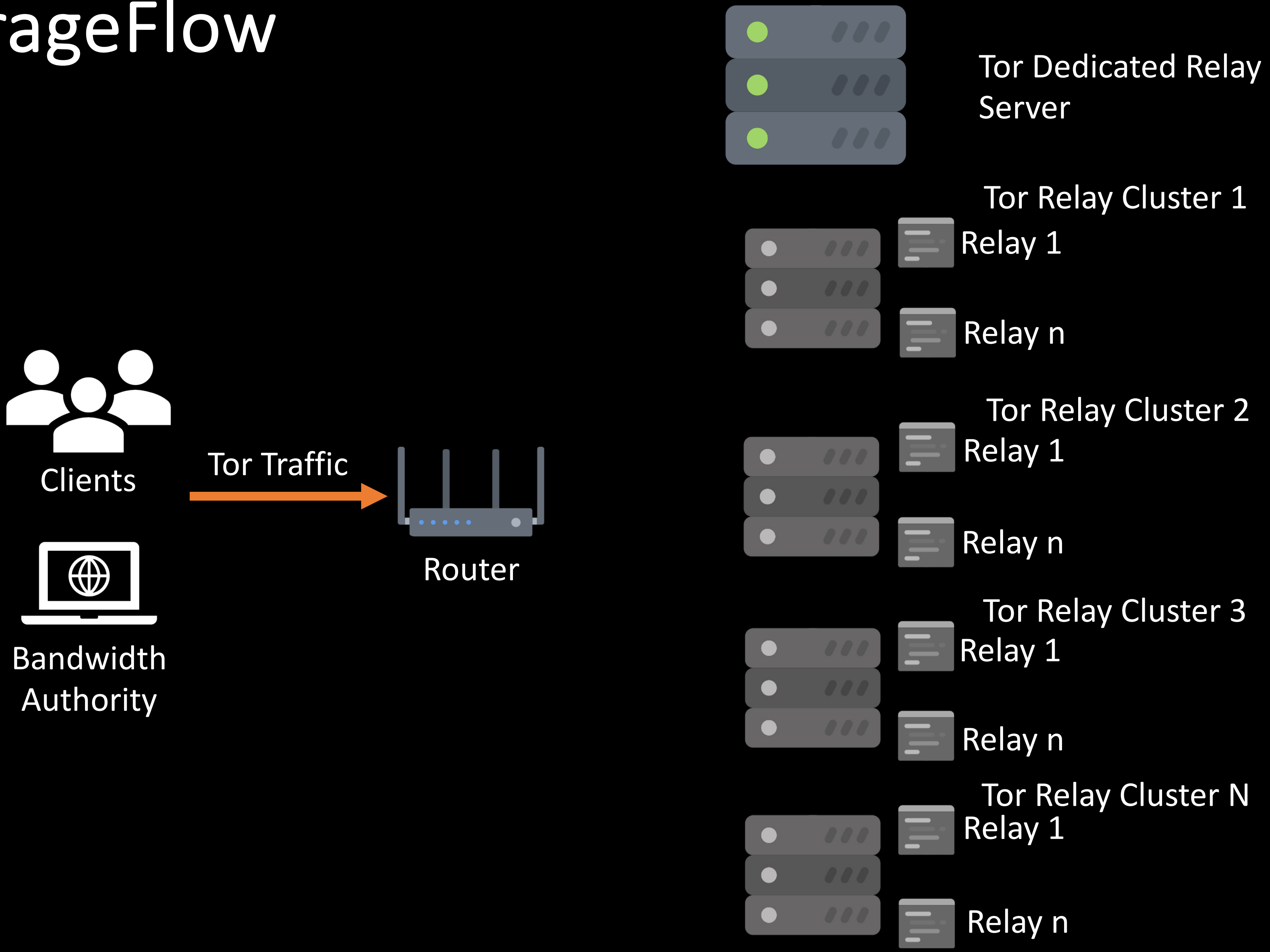


Tor Dedicated Relay Server

Tor Relay Cluster 1

Relay 1

Relay n

Tor Relay Cluster 2

Relay 1

Relay n

Tor Relay Cluster 3

Relay 1

Relay n

Tor Relay Cluster N

Relay 1

Relay n

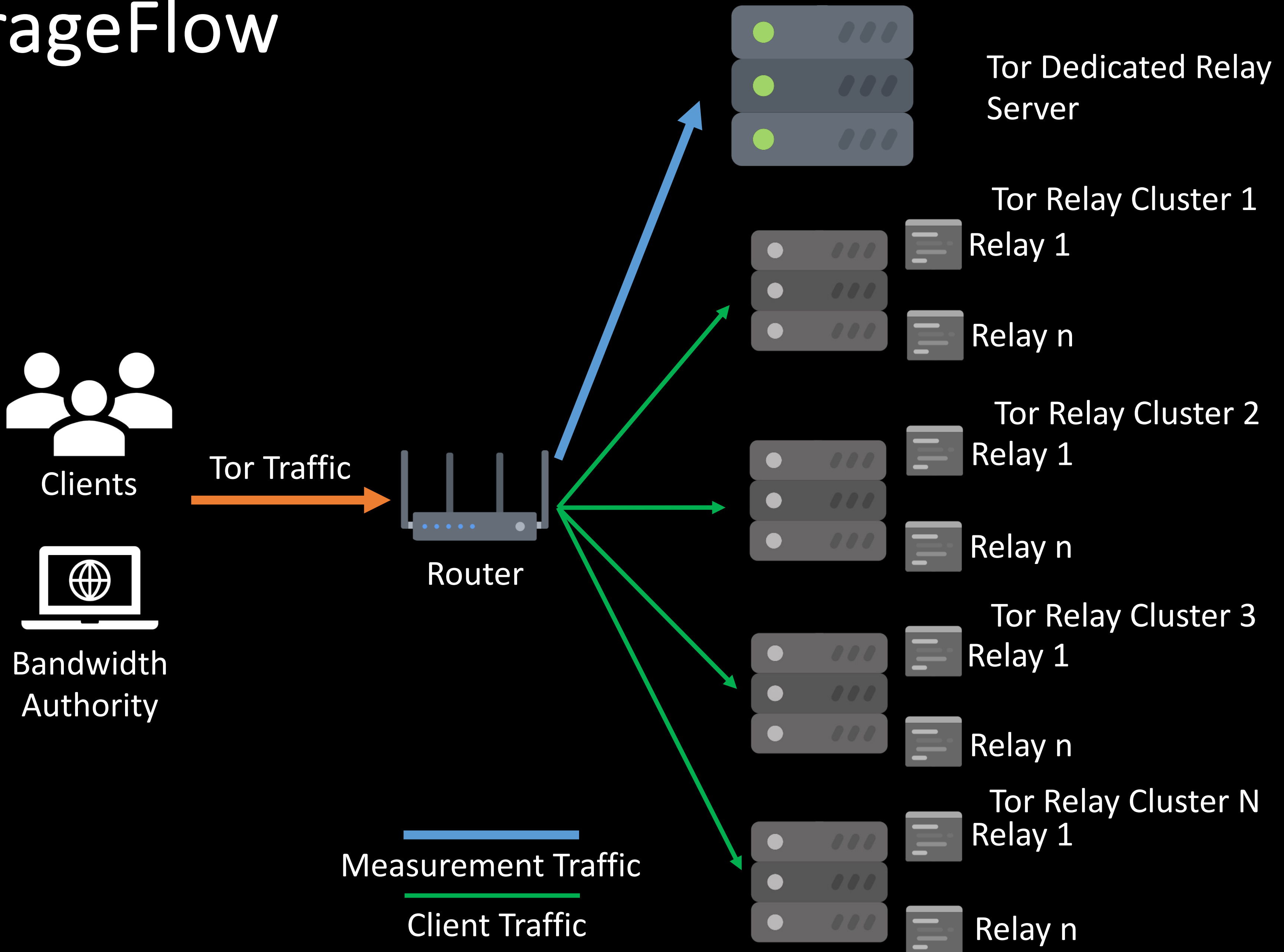
Clients

Tor Traffic

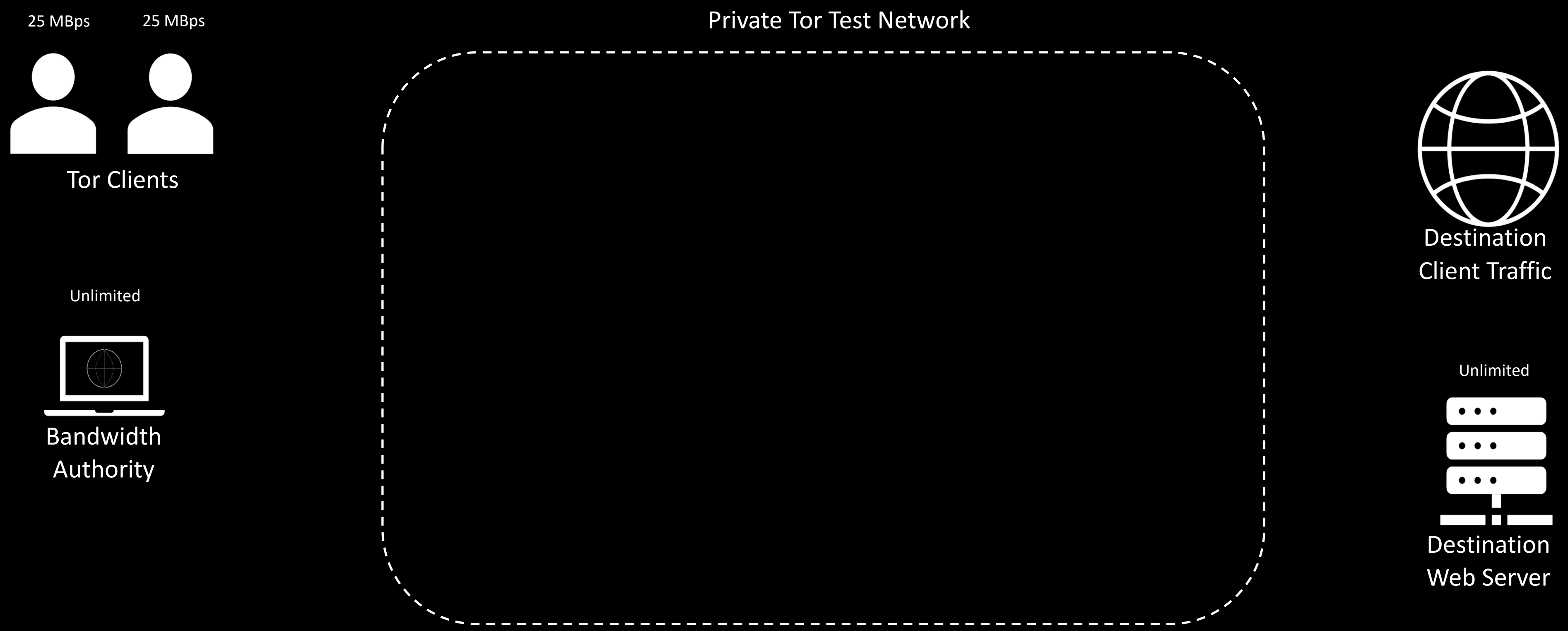
Router

Bandwidth Authority

D-MirageFlow



Evaluation Setup



25 MBps

25 MBps

Tor Clients

Unlimited

Bandwidth Authority

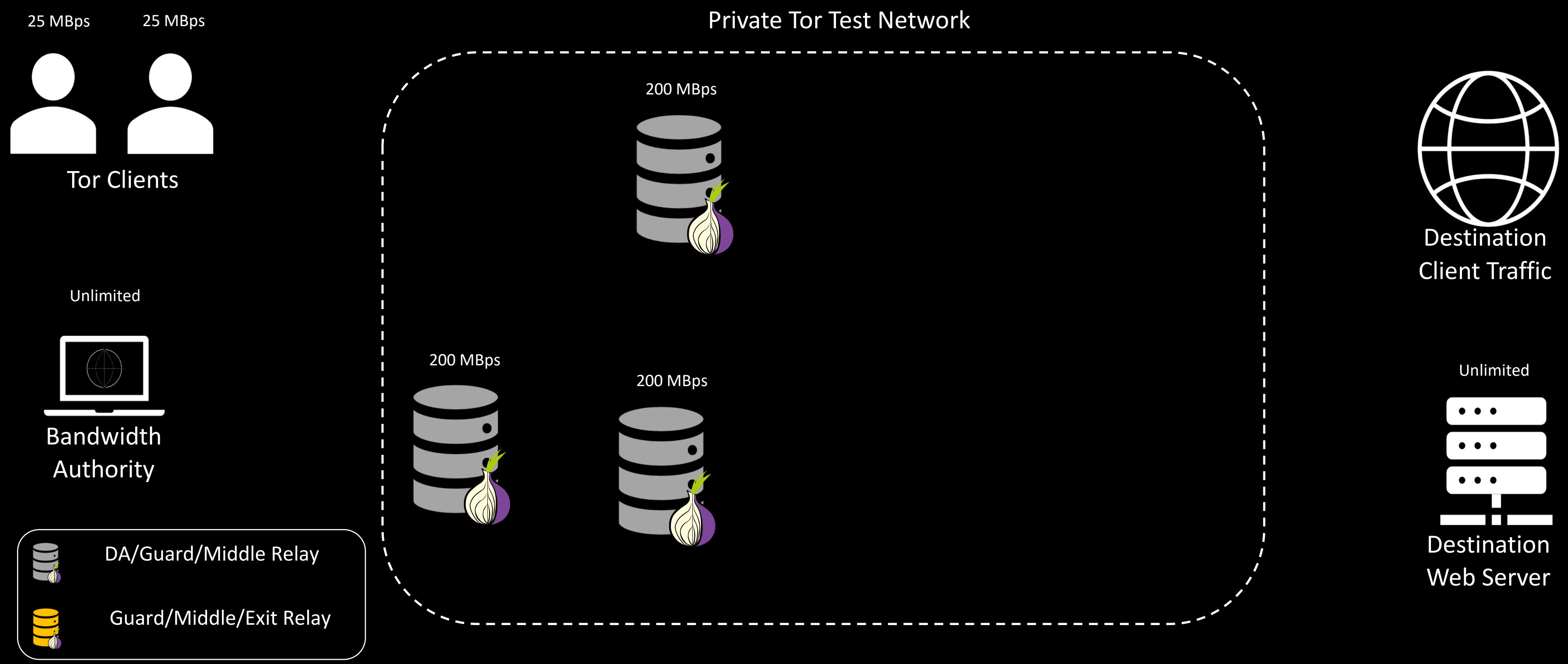
Private Tor Test Network

Destination Client Traffic

Unlimited

Destination Web Server

Evaluation Setup



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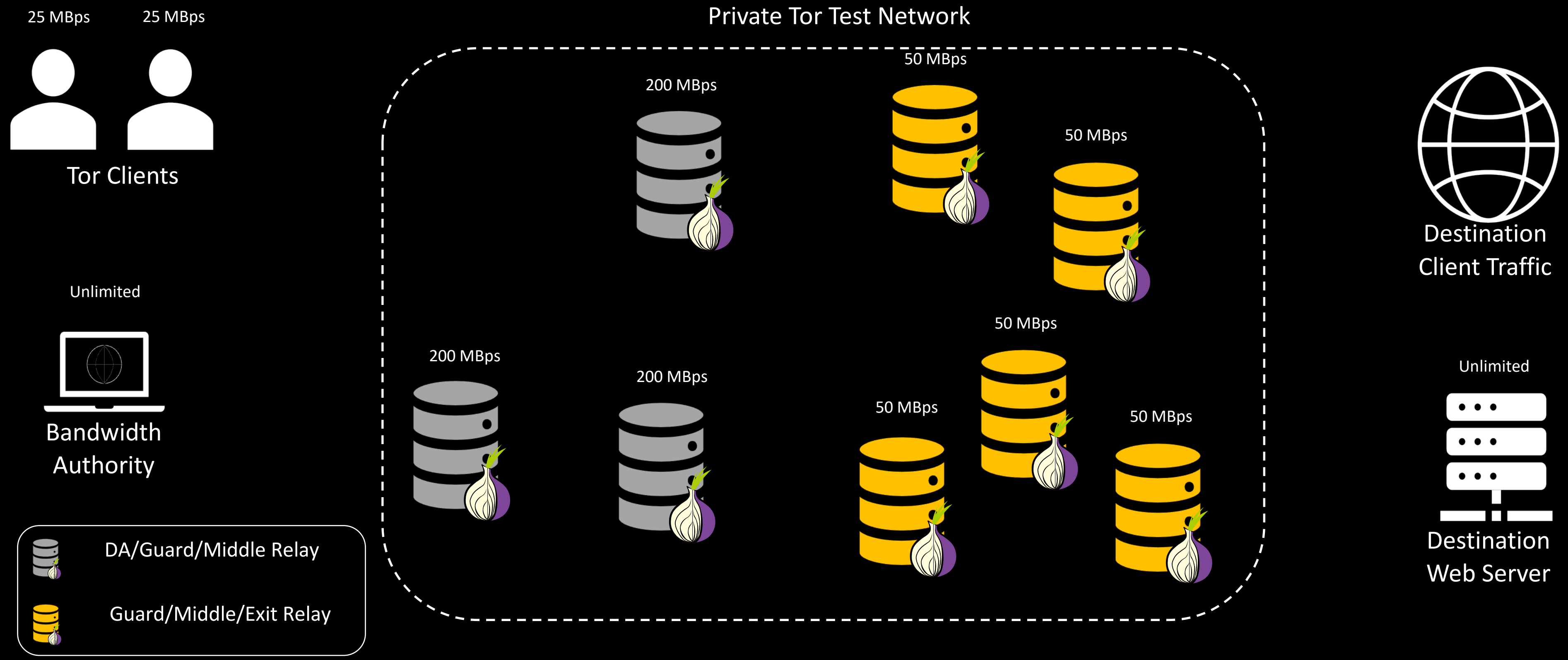

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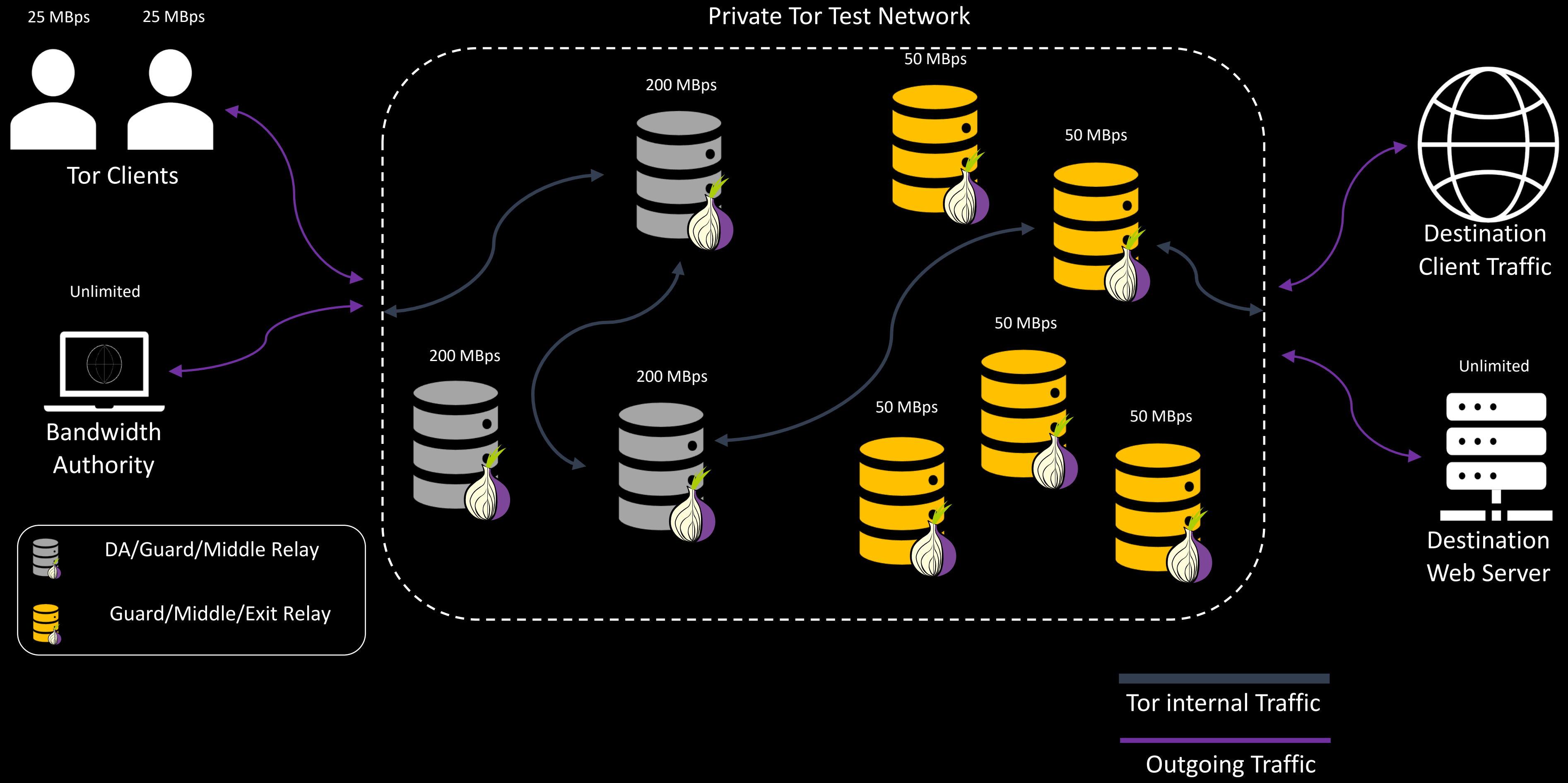

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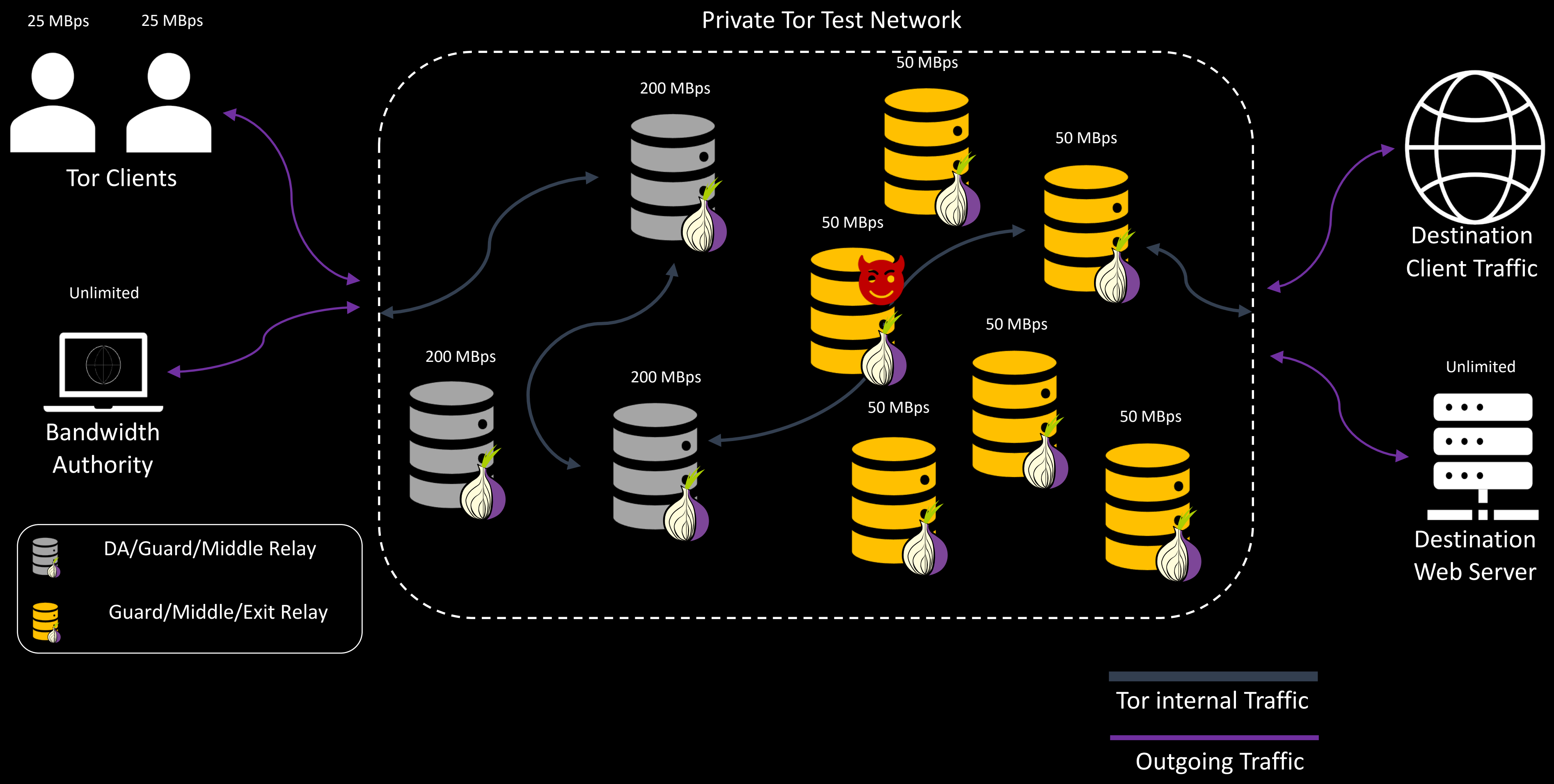

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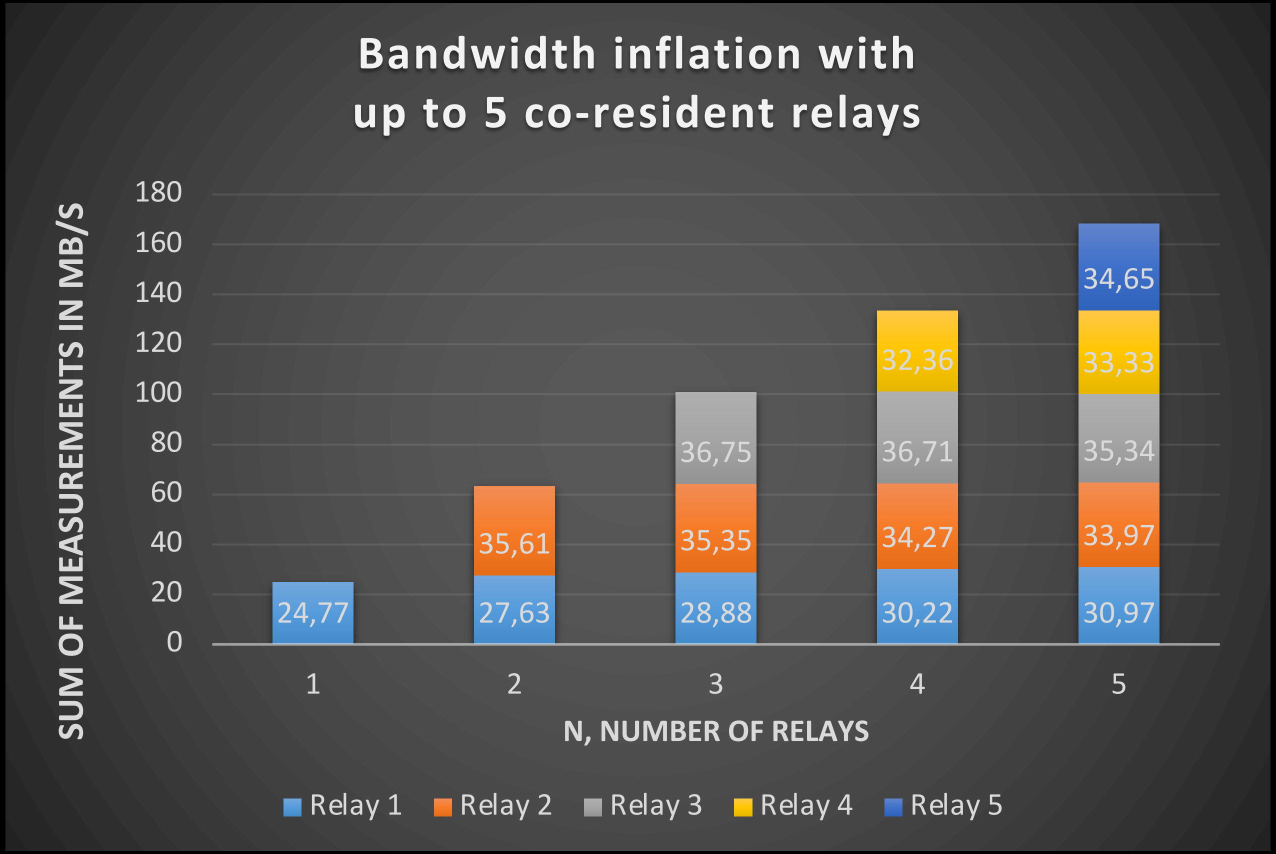

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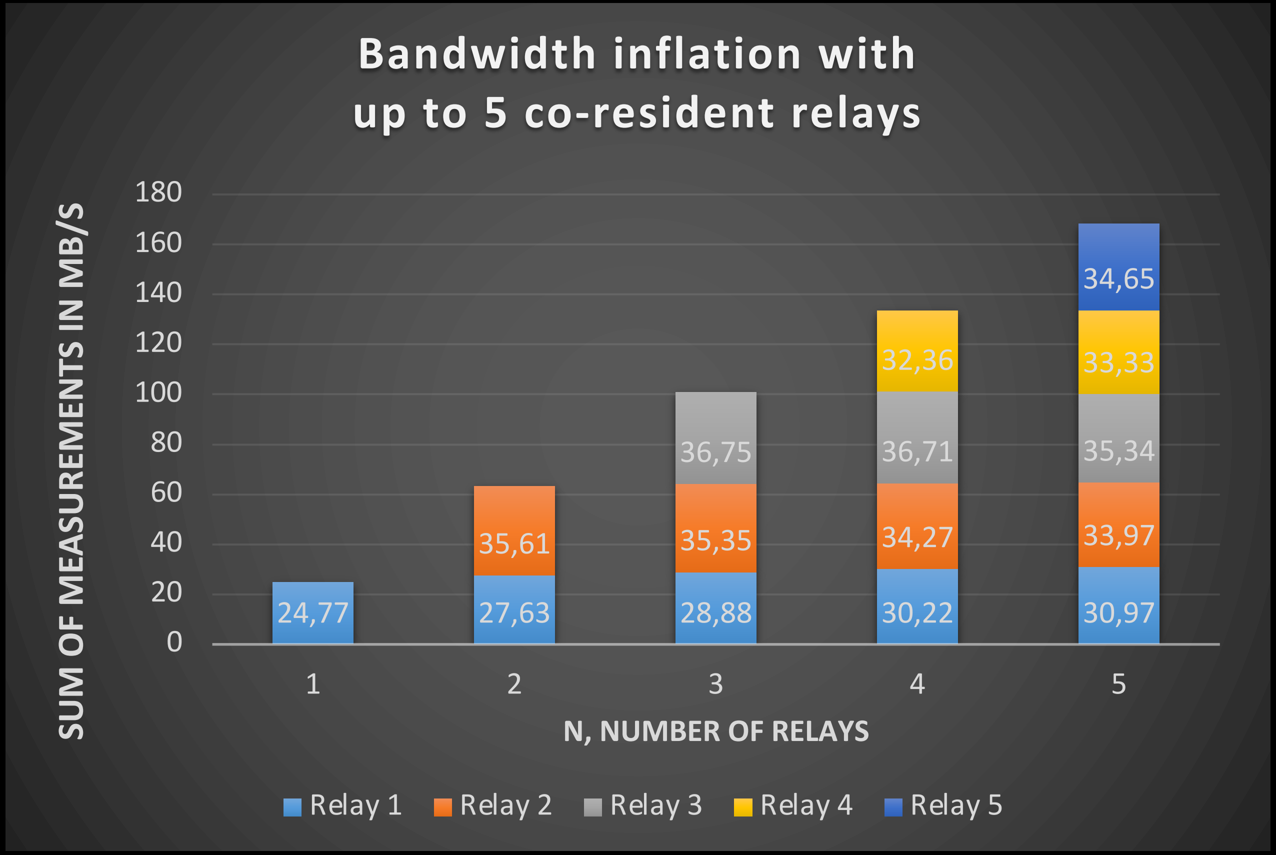
- Inflation of up to 336% (168 MB/s) for five relays can be achieved



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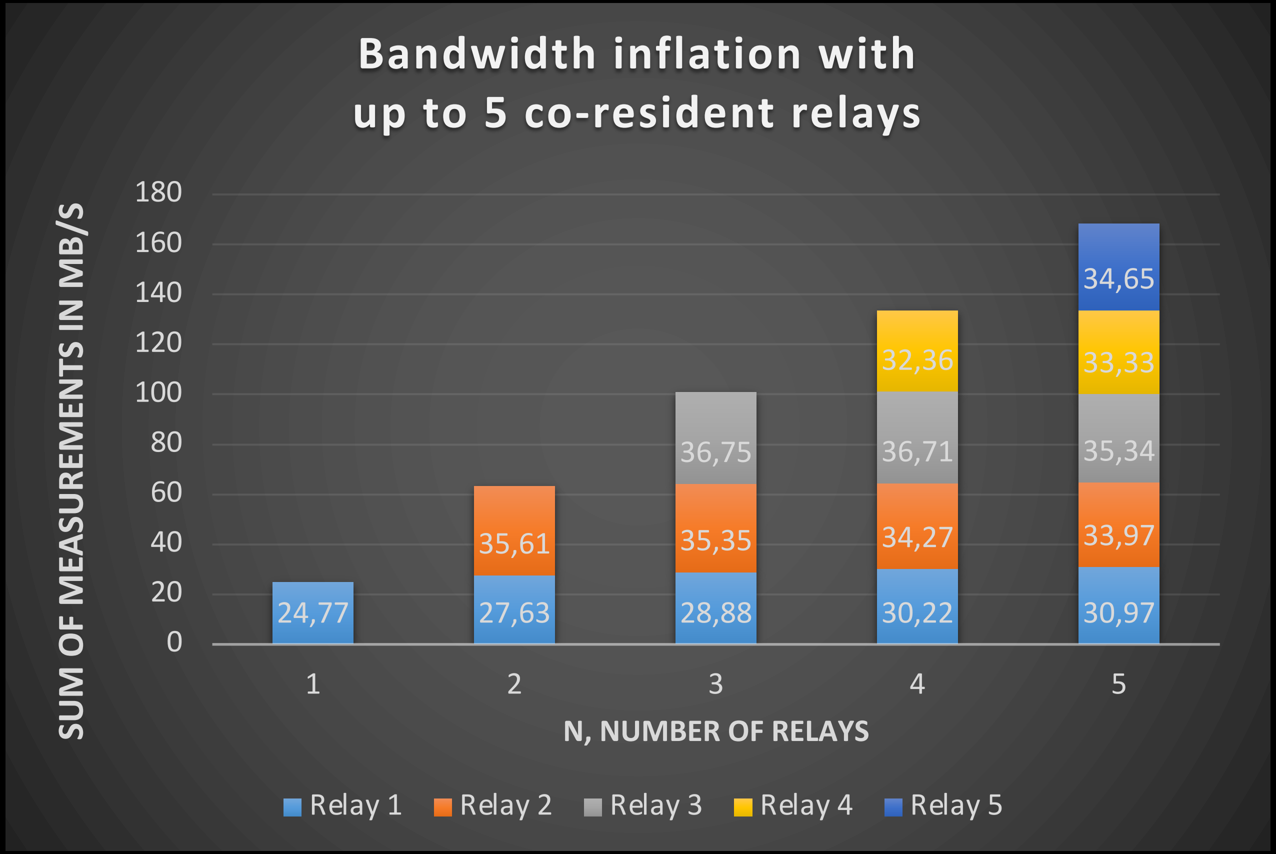
- The server has a bandwidth of 50 MB/s
- Inflation of up to 336% (168 MB/s) for five relays can be achieved
- Achieves an inflation factor close to N based on measurement of the first relay



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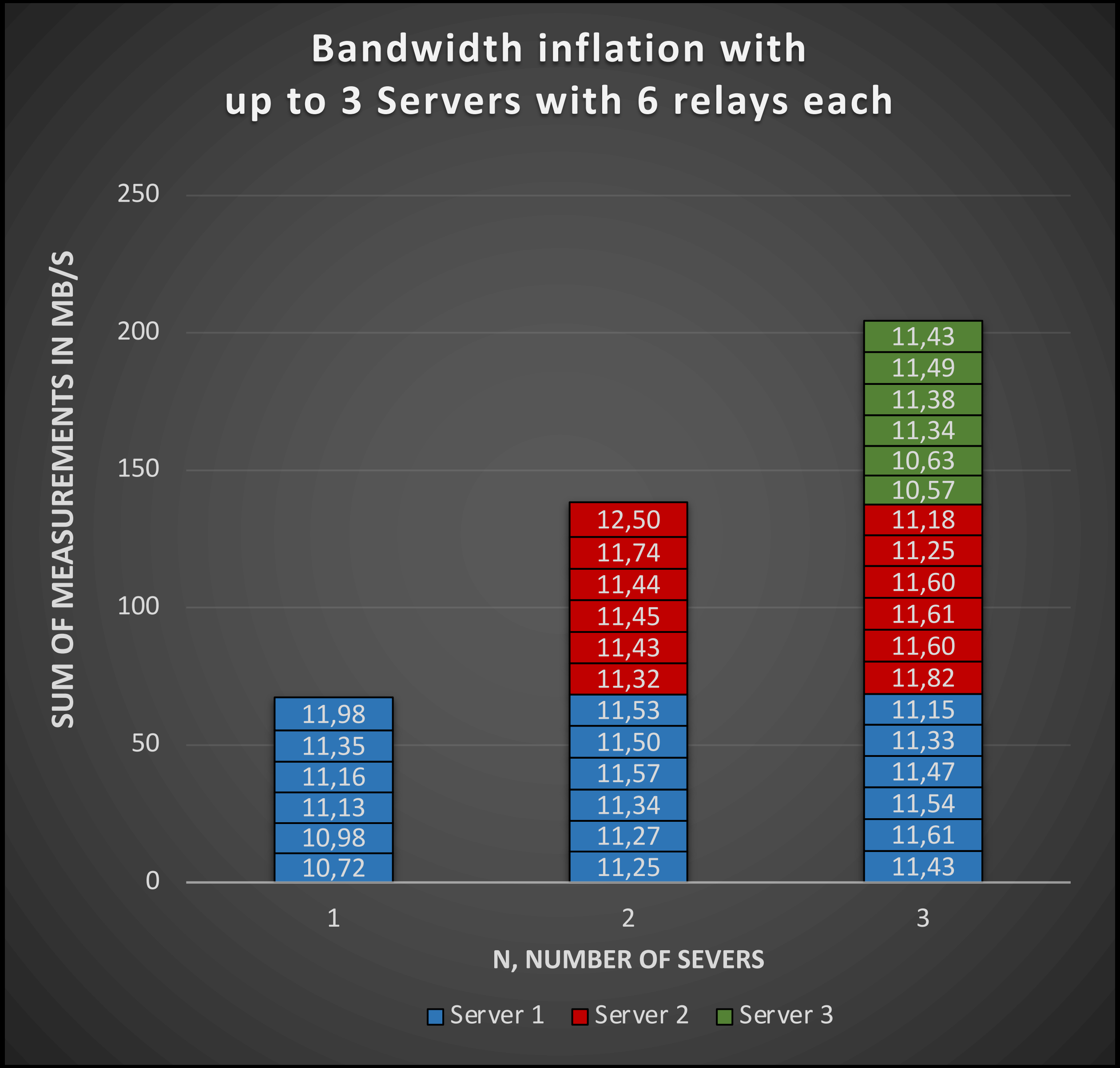

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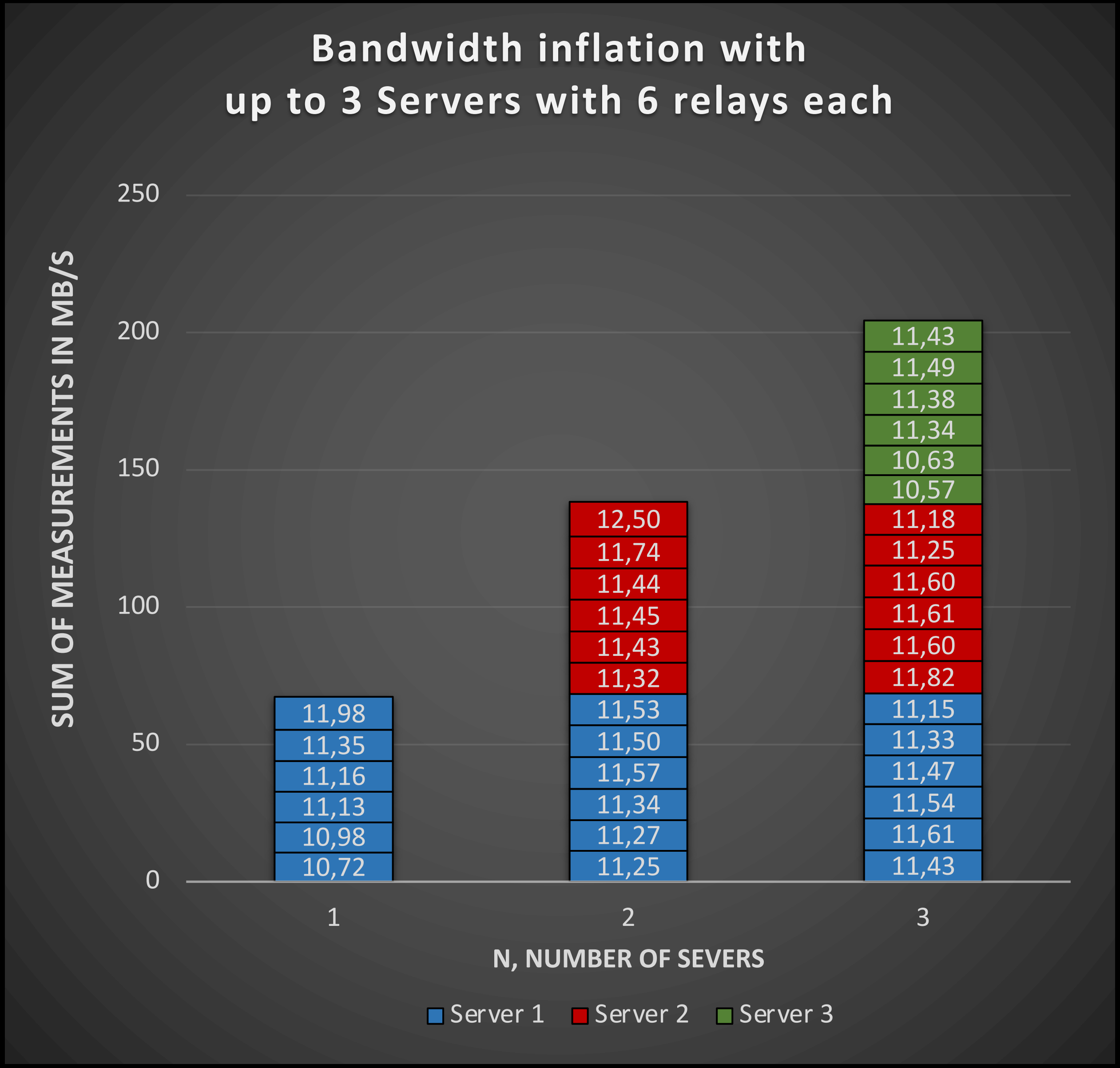
- A dedicated server and router with a bandwidth of 50MB/s each were utilized
- The total measured bandwidth was inflated by 272% (204MB/s)



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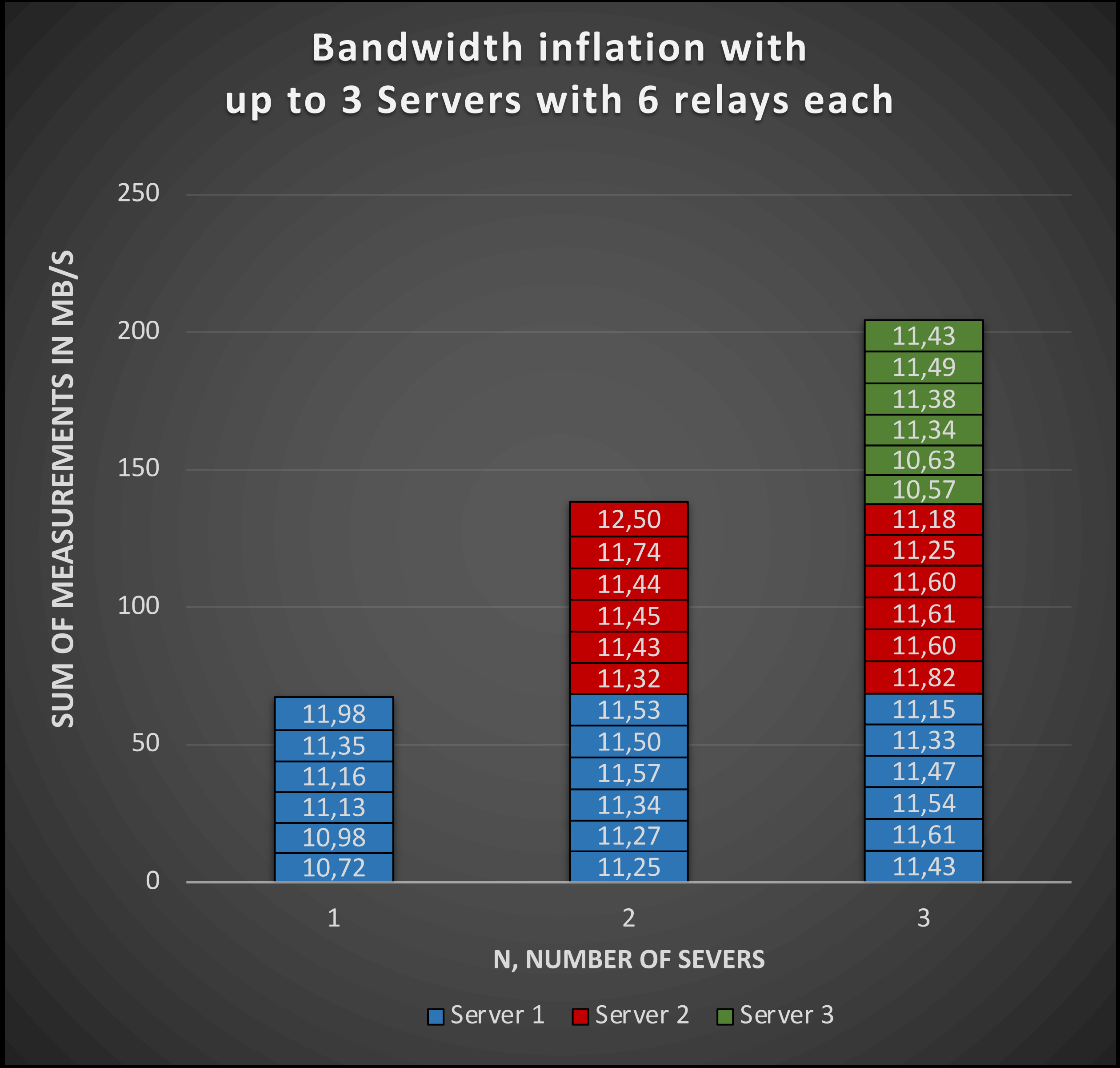
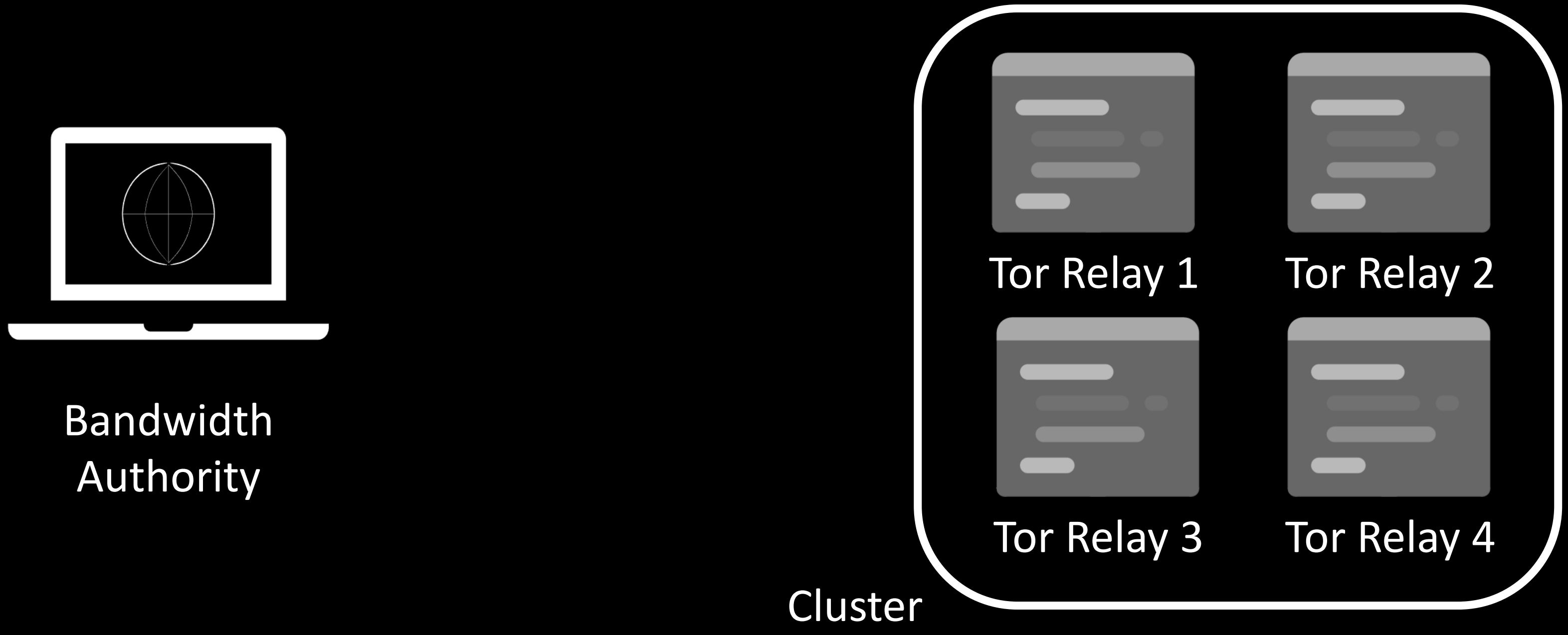
- Achieves an inflation factor close to n*N (n number of relays and N number of servers) based on measurement of the first relay


Bandwidth inflation with up to 3 Servers with 6 relays each

Limitation: Co-Measurement



Bandwidth Authority

Tor Relay 1

Tor Relay 2

Tor Relay 3

Tor Relay 4

Cluster

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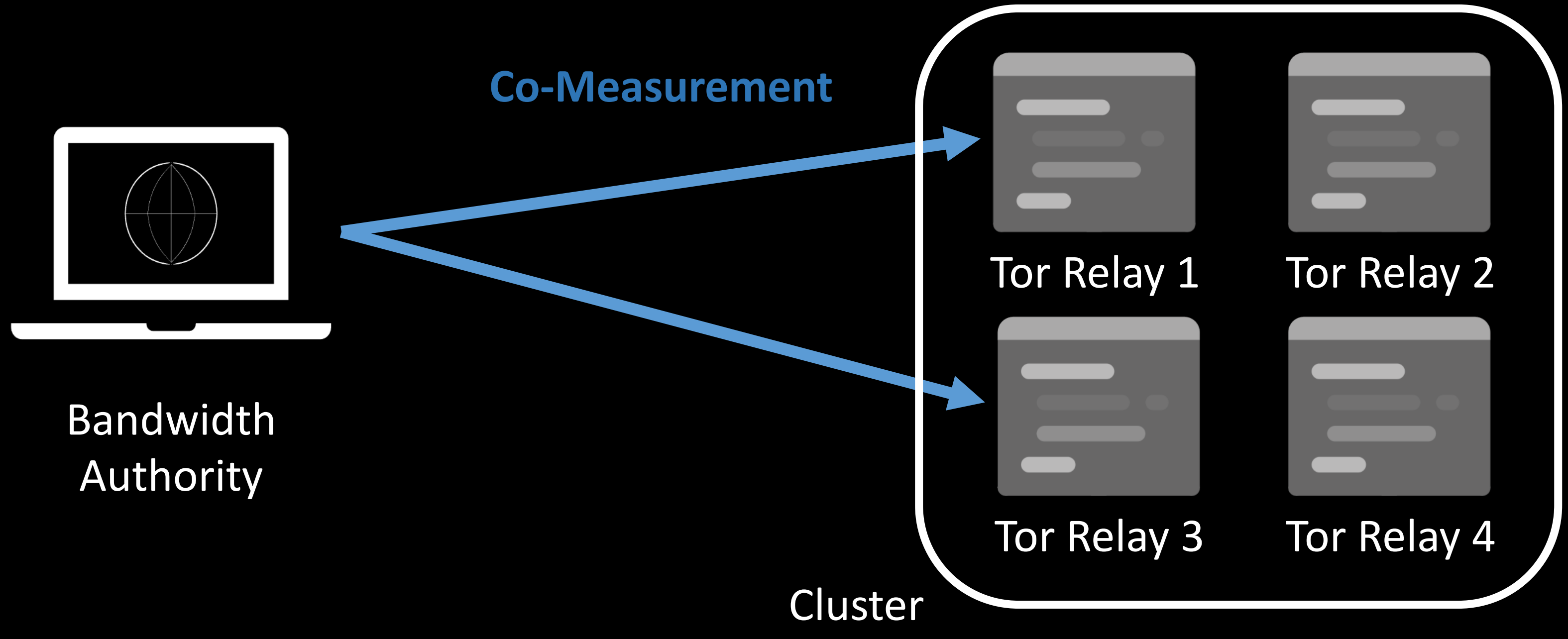

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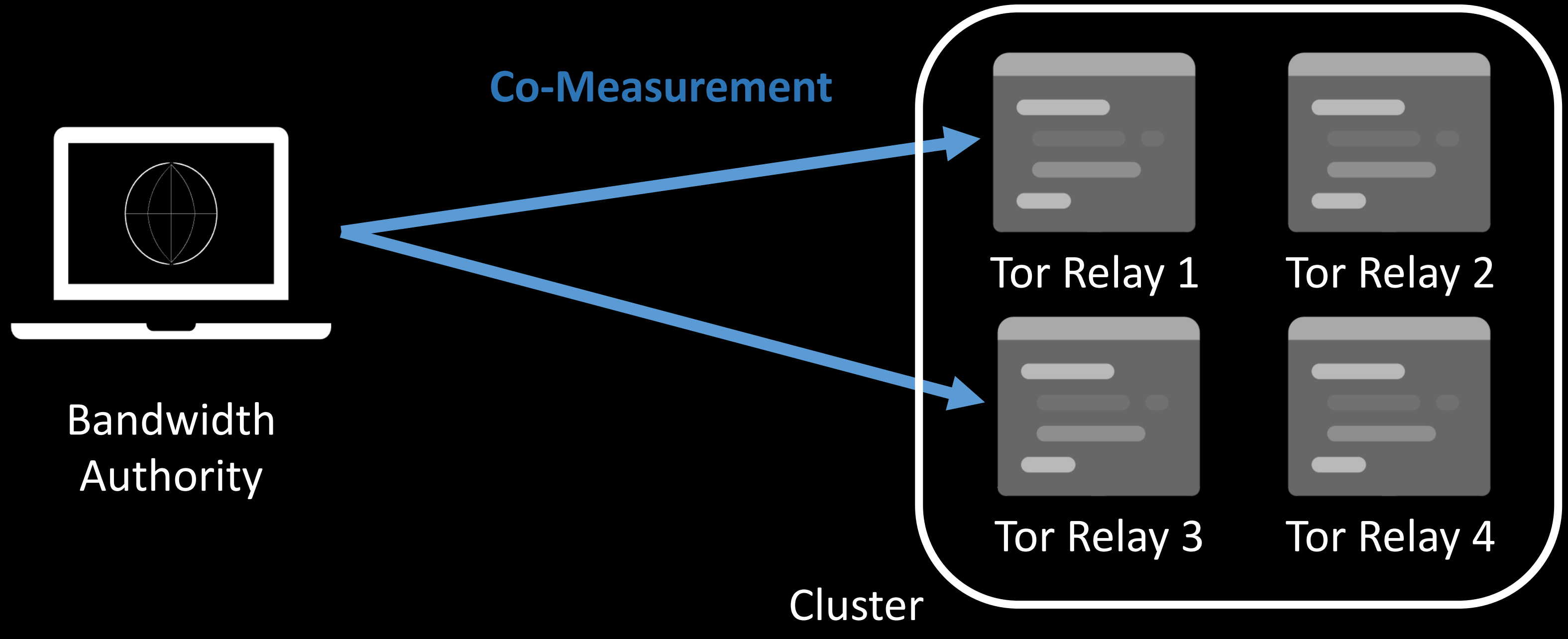

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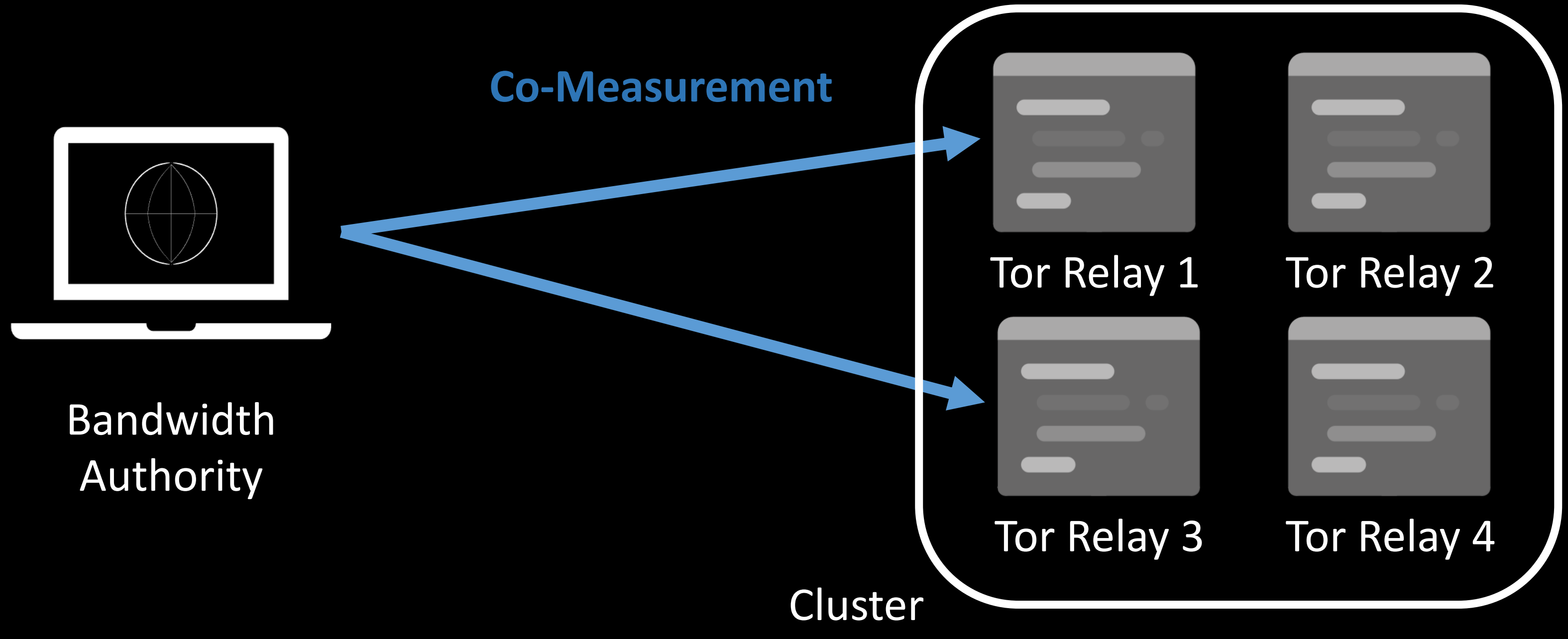

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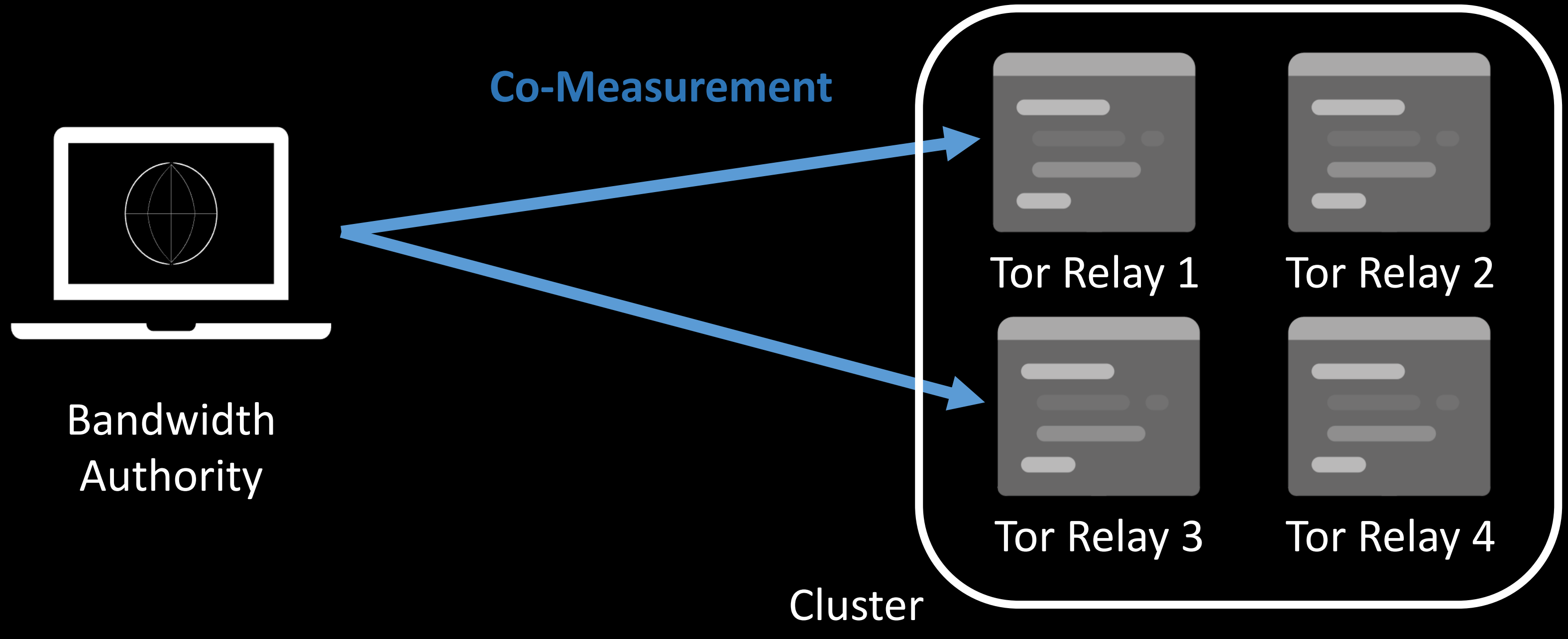

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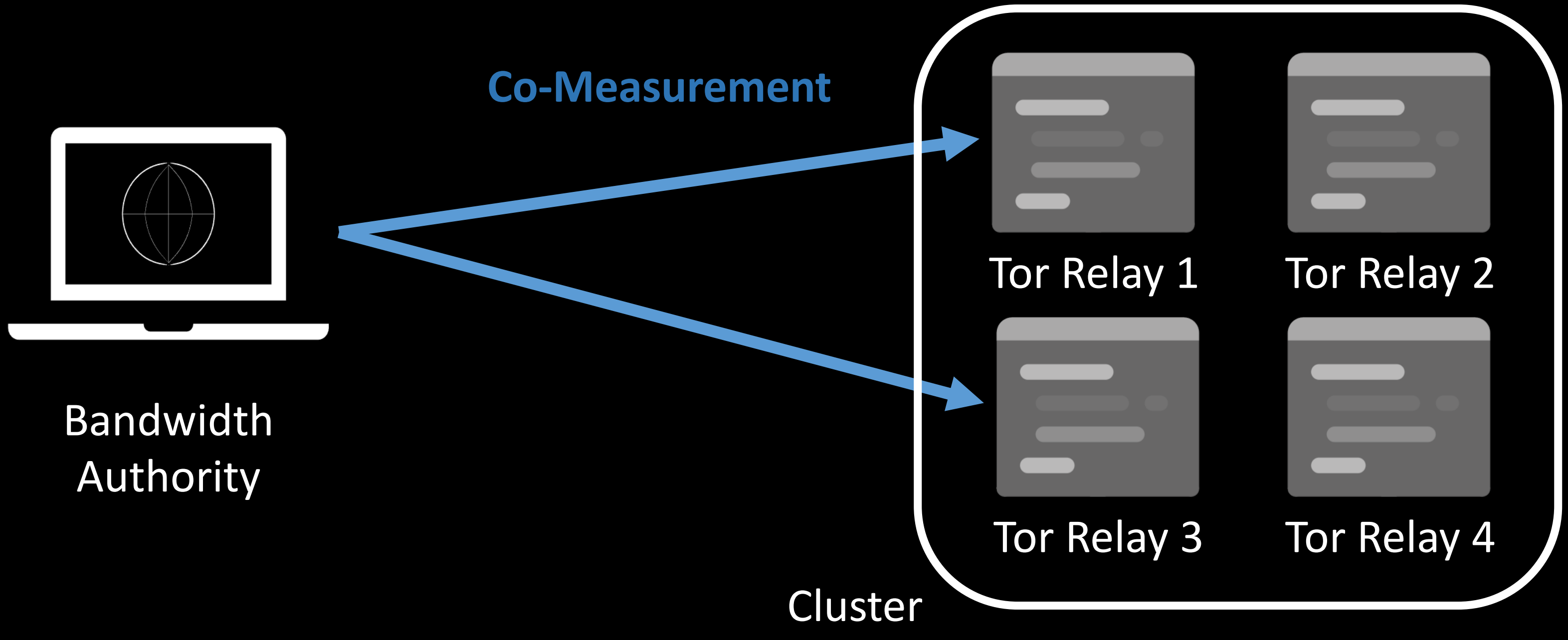

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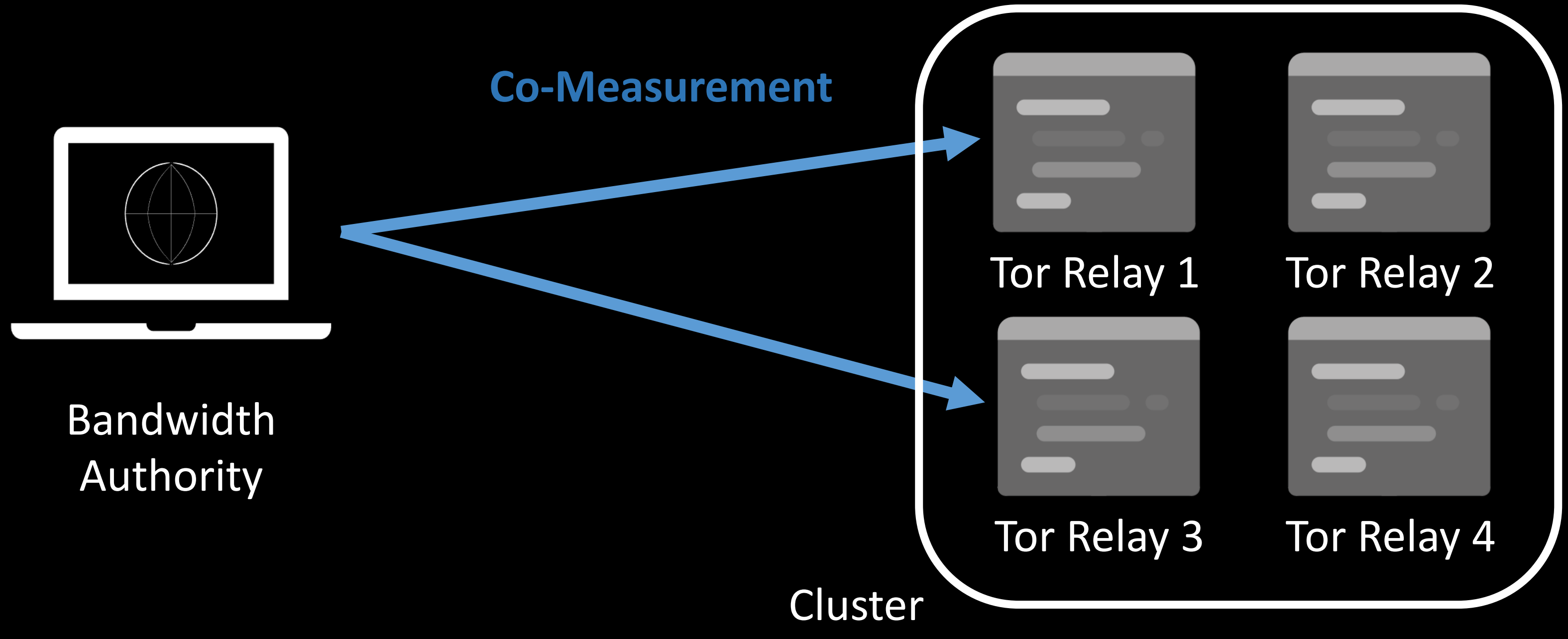

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- Inflation factor of up to 92 times with 120 relays is theoretically possible
- With 10 dedicated servers (100MB/s and 109 relays each) running the MirageFlow attack 50% of Tor’s traffic can be controlled

Countermeasures

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Active detection by probing

Countermeasures

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Eliminating Explicit Measurement Traffic

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- BAs, however, have all the necessary information

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- Countermeasures are either limited or not very practical
- There is a need for a more resilient measurement solution